ERDA/JPL 954374-77/4

Distribution Category - UC-63

SLICING OF SILICON INTO SHEET MATERIAL

Silicon Sheet Growth Development for the
Large Area Silicon Sheet Task of the Low
Cost Silicon Solar Array Project

SEVENTH QUARTERLY REPORT

By

S. C. HOLDEN

J. R. FLEMING

January 12, 1978

Reporting Period September 19, 1977 to December 17, 1977

JPL Contract No. 954374

Varian Associates
Lexington Vacuum Division
121 Hartwell Avenue
Lexington, Massachusetts 02173

This work was performed for the Jet Propulsion Laboratory, California Institute of Technology, under NASA Contract NAS7-100 for the U. S. Energy Research and Development Administration, Division of Solar Energy.

The JPL Low-Cost Silicon Solar Array Project is funded by ERDA and forms part of the ERDA Photovoltaic Conversion Program to initiate a major effort toward the development of low-cost solar arrays.

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1.0 SUMMARY

During the past quarter fabrication was begun on a prototype large capacity multiple blade slurry saw. Final concept and design is nearly complete on the bladehead which will tension up to 1000 blades, and cut a 45 cm long silicon ingot as large as 12 cm in diameter. The large blade tensioning force of 270,000 kg (600,000 lbg) will be applied through two bolts acting on a pair of scissor toggles, significantly reducing operator set-up time.

Poor wafering yields have caused concern in recent tests with MS slicing. The cause for poor yield, namely perimeter fracture of slices, also impacts the solar cell production yield of 10 cm diameter thin (250-350μ) silicon slices. Recent tests with an "upside-down" cutting technique has resulted in 100% wafering yields and the highest wafer accuracy yet experienced with MS slicing.

Variations in oil and abrasive have resulted only in degraded slicing results. A technique of continuous abrasive slurry separation to remove silicon debris is described.

2.0 INTRODUCTION

Phase II of an effort by Varian to reduce the cost of multiblade slurry wafering of silicon for 1982 silicon sheet production cost goals involves construction of a large scale prototype MS wafering saw and numerous test programs to reduce the costs and improve the capabilities of the MS technique.

The standard form of the MS wafering technique has been shown to have cost effective potential for low cost solar array production. However, improvements in the technique cannot yet be formulated from basic understanding of the fundamental cutting technology. Recent experience has demonstrated that a more complete technical perception must be gained in order to effectively develop improvements.

An example of this dilemma is the lack of success of the multiple blade alignment device. It was felt that improved blade alignment with this method would result in significant process improvements. However, to date, no major improvements have been seen. A major objective of the next quarter will be to review the current technology understanding in light of recent results and formulate a modified approach.

3.0 CUTTING TESTS AND WAFER CHARACTERIZATION

Table 1 shows a summary of all MS slicing tests during this quarter. A severe reduction in slice yield has occurred during the second phase of this program. The slices which do survive the slicing operation have occasional cracks in the perimeter. The source of these cracks has not been explained or resolved despite efforts to modify slurry application, improvements in machine alignment and other changes. The one exception has been the upside down cutting tests where 100% yield was experienced.

It must be noted that most tests involve very thin slicing of 10 cm silicon wafers where a borderline survival condition may exist. Also wide variations in composition of the abrasive slurry has been explored and failures are not surprising.

3.1 Slurry/Oil Tests

The object of this series of cutting tests is to explore the use of lower cost abrasive mixtures in MS slicing. Broader particle size distributions may have effective cost leverage since fine gradiations are more difficult to achieve. Oil tests are preliminary to tests involving oil viscosity and settling rate. This would indicate proper parameters for use with lower cost of recycled oils.

3.1.1 Mixed Abrasive: Test #2-3-05

For this test, the abrasive consisted of equal parts of #600 and #800 SiC. Other conditions were standard. This test was to investigate both reduction of kerf with mixed abrasive and the effect of the amount of spread in particle sizes.

Efficiency, abrasion rate, productivity and kerf loss were normal. The yield was very low, only 29%. Slice taper and bow could not be measured since the wafers activated the out-of-range warning on the measuring device.

TABLE I

SLICING TEST SUMMARY

PARAMETER TEST	2-3-06	2-3-07	2-3-08	2-3-09
Material	100 Si	100 Si	100 Si	100 Si
Size (mm)	100	100	100	100
Area/Slice (cm^2)	78.54	78.54	78.54	78.54
Blade Thickness (mm)	0.15 x 6.35	0.15 x 6.35	0.15 x 6.35	0.15 x 6.35
Spacer Thickness (mm)	0.36	0.36	0.36	0.36
Blade Height (mm)	6.4	6.4	6.4	6.4
Number of Blades	270	131	150	136
Load (gram/blade)	85	85	85	85
Sliding Speed (cm/sec)	63.76		61.15	64.44
Abrasive (type/grit size)	#600 SiC	#600/800/ 1000 Sic	#600/800/ 1000 SiC	#600 SiC
Oil Volume (liters)	7.6 Lub.	7.6 PC	7.6 PC	7.6 Lub.
Mix (kg/liter)	0.24	0.18 Total	0.36 Total	0.12
Slice Thickness (mm)	0.292		0.320	0.304
Kerf Width (mm)	0.216		0.188	0.204
Abrasive Kerf Loss (mm)	0.064		0.038	0.052
Cutting Time (hours)	34.25	23.20	44.10	36.20
Efficiency (full test)	0.93		0.656	0.81
(typical)	1.15		0.812	1.06
(maximum)	1.27		0.939	1.28
Abrasion Rate (full test)	.050		.034	.044
(cm^3/hr/bl) (typical)	.062		.042	.058
(maximum)	.069		.049	.070
Productivity (full test)	2.29	3.39	1.78	2.17
(cm^2/hr/bl) (typical)	2.87		2.23	2.84
(maximum)	3.19		2.60	3.43
Yield	52/269 19%	4/130 3%	17/149 11%	16/135 12%
Slice Taper (mm)	.065		.101	.078
Slice Bow (mm)	.054		.107	.168
Abrasive Utilization (cm^3/kg)	251.3		81.1	239.2
Oil Utilization (cm^3/liter)	60.3		29.2	28.7
Blade Wear Ratio (cm^3/cm^3)	.054		.067	.064

TABLE I
(continued)

SLICING TEST SUMMARY

PARAMETER TEST	2-3-10	2-4-04	2-4-05	2-5-03
Material	100 Si	100 Si	100 Si	100 Si
Size (mm)	100	100	100	100
Area/Slice (cm^2)	78.54	78.54	78.54	78.54
Blade Thickness (mm)	0.15 x 6.35	0.15 x 6.35	0.20 x 6.35	0.15 x 6.35
Spacer Thickness (mm)	0.41	0.41	0.41	0.41
Blade Height (mm)	6.4	6.4	6.4	6.4
Number of Blades	131	271	78	125
Load (gram/blade)	85	85	113.4	113.4
Sliding Speed (cm/sec)		65.3	61.14	65.73
Abrasive (type/grit size)	#600 SiC	#600 SiC	#600 SiC	#600 SiC
Oil Volume (liters)	7.6 Lub.	7.6	7.6 PC	7.6 PC
Mix (kg/liter)	0.06	0.36	0.48	0.48
Slice Thickness (mm)		0.322	0.333	0.341
Kerf Width (mm)		0.237	0.277	0.269
Abrasive Kerf Loss (mm)		0.087	0.074	0.069
Cutting Time (hours)	44.55	26.55	36.50	25.05
Efficiency (full test)		1.25	0.87	1.13
(typical)		1.53	1.42	1.30
(maximum)		1.733	1.85	1.66
Abrasion Rate (full test)		.069	.060	0.084
(cm^3/hr/bl) (typical)		.085	.098	0.097
(maximum)		.096	.128	0.123
Productivity (full test)	1.76	2.91	2.15	3.14
(cm^2/hr/bl) (typical)		3.59	3.54	3.61
(maximum)		4.06	4.62	4.58
Yield	5/130 4%	78/270 29%	42/77 55%	124/124 100%
Slice Taper (mm)		0.044	.066	0.044
Slice Bow (mm)		0.046	.057	0.030
Abrasive Utilization (cm^3/kg)		184.2	46.5	72.3
Oil Utilization (cm^3/liter)		66.3	22.3	34.7
Blade Wear Ratio (cm^3/cm^3)		.052		0.048

TABLE I
(continued)

SLICING TEST SUMMARY

PARAMETER TEST	2-5-04	2-5-06	2-6-01	2-6-02
Material	100 Si	100 Si	100 Si	100 Si
Size (mm)	100	100	100	100
Area/Slice (cm^2)	78.54	78.54	78.54	78.54
Blade Thickness (mm)	0.15 x 6.35		0.15 x 6.35	0.15 x 6.35
Spacer Thickness (mm)	0.41		0.36	0.36
Blade Height (mm)	6.4		6.4	6.4
Number of Blades	136		150	138
Load (gram/blade)	85		127.6/85	85
Sliding Speed (cm/sec)	65.21		63.42	
Abrasive (type/grit size)	#600 SiC		#600 SiC	#600 SiC
Oil Volume (liters)	7.6 PC		7.6 PC	7.6 PC
Mix (kg/liter)	0.36		0.36	0.24
Slice Thickness (mm)	0.330		0.287	0.300
Kerf Width (mm)	0.229		0.221	0.208
Abrasive Kerf Loss (mm)	0.076		0.068	0.056
Cutting Time (hours)	65.55		22.55	12.35
Efficiency (full test)	0.49		1.15	
(typical)	1.33		1.59	
(maximum)	2.06		2.00	
Abrasion Rate (full test)	.027		.077	
(cm^3/hr/bl) (typical)	.073		.107	
(maximum)	.114		.134	
Productivity (full test)	1.20		3.48	
(cm^2/hr/bl) (typical)	3.19		4.84	
(maximum)	4.98		6.06	
Yield	96/135 71%		120/149 81%	0/137 0%
Slice Taper (mm)	.090		.075	
Slice Bow (mm)	.137		.020	
Abrasive Utilization (cm^3/kg)	89.4		95.3	
Oil Utilization (cm^3/liter)	32.2		34.3	
Blade Wear Ratio (cm^3/cm^3)	.048		.054	

TABLE I
(continued)

SLICING TEST SUMMARY

PARAMETER TEST		2-6-03	2-6-04		
Material		100 Si	100 Si		
Size	(mm)	100	100		
Area/Slice	(cm^2)	78.54	78.54		
Blade Thickness	(mm)	0.15 x 6.35	0.15 x 6.35		
Spacer Thickness	(mm)	0.36	0.36		
Blade Height	(mm)	6.4	6.4		
Number of Blades		150	150		
Load	(gram/blade)	85	85		
Sliding Speed	(cm/sec)	63.24	62.23		
Abrasive	(type/grit size)	#600 SiC	#600 SiC		
Oil Volume	(liters)	7.6 PC	7.6 PC		
Mix	(kg/liter)	0.36	0.36		
Slice Thickness	(mm)	0.274	0.267		
Kerf Width	(mm)	0.234	0.241		
Abrasive Kerf Loss	(mm)	0.082	0.091		
Cutting Time	(hours)	28.20	30.50		
Efficiency	(full test)	1.21	1.16		
	(typical)	1.64	1.75		
	(maximum)	1.91	2.09		
Abrasion Rate	(full test)	.065	.061		
(cm^3/hr/bl)	(typical)	.088	.092		
	(maximum)	.102	.110		
Productivity	(full test)	2.79	2.53		
(cm^2/hr/bl)	(typical)	3.76	3.82		
	(maximum)	4.36	4.56		
Yield		80/149 54%	99/149 66%		
Slice Taper	(mm)	.060	.079		
Slice Bow	(mm)	.059	.086		
Abrasive Utilization	(cm^3/kg)	100.8	103.9		
Oil Utilization	(cm^3/liter)	36.3	37.4		
Blade Wear Ratio	(cm^3/cm^3)	.046	.047		

TABLE 2

WAFER THICKNESS CHARACTERIZATION SUMMARY

PARAMETER	TEST		2-3-06	2-3-07	2-3-08	2-3-09
SLICE	Diameter	(mm)	100	100	100	100
	Area	(cm^2)	78.5	78.5	78.5	78.5
THICKNESS	Average	μ	292.1		319.5	303.7
	Std. Dev.	μ	39.7		34.0	38.0
TOTAL VARIATION	Average	μ	60.4		58.9	57.6
	Std. Dev.	μ	21.2		18.3	37.0
STD. DEVIATION	Average	μ	23.8		20.8	20.4
	Std. Dev.	μ	8.7		7.2	15.8
VERTICAL TTV	Average	μ	65.4		100.8	78.2
	Maximum	μ	111.9		140.6	226.7
	Minimum	μ	32.9		79.1	45.6
HORIZONTAL TTV	Average	μ	18.6		26.4	17.5
	Maximum	μ	38.3		35.7	46.8
	Minimum	μ	6.2		18.1	7.0
VERTICAL BOW	Average	μ	52.6		118.0	159.0
	Maximum	μ	117.6		161.0	173.5
	Minimum	μ	18.4		70.9	144.7
HORIZONTAL BOW	Average	μ	63.9		41.7	30.7
	Maximum	μ	86.2		64.2	50.9
	Minimum	μ	24.0		26.7	12.6
VERTICAL CL BOW	Average	μ	108.7		214.1	335.3
	Maximum	μ	209.7		365.2	392.3
	Minimum	μ	38.6		81.2	171.9
HORIZONTAL CL BOW	Average	μ	139.4		70.1	43.3
	Maximum	μ	195.2		107.6	65.4
	Minimum	μ	40.2		20.5	27.8

TABLE 2
(continued)

WAFER THICKNESS CHARACTERIZATION SUMMARY

PARAMETER	TEST		2-3-10	2-4-04	2-4-05	2-5-03
SLICE	Diameter	(mm)	100	100	100	100
	Area	(cm^2)	78.5	78.5	78.5	78.5
THICKNESS	Average	μ		322	332.6	341.1
	Std. Dev.	μ		21.7	21.7	21.0
TOTAL VARIATION	Average	μ		35.6	63.8	35.1
	Std. Dev.	μ		23.3	19.7	14.9
STD. DEVIATION	Average	μ		13.7	24.6	13.3
	Std. Dev.	μ		10.2	7.8	6.3
VERTICAL TTV	Average	μ		44.0	65.9	44.3
	Maximum	μ		137.2	102.1	72.5
	Minimum	μ		17.4	34.3	21.8
HORIZONTAL TTV	Average	μ		9.0	15.3	11.5
	Maximum	μ		17.7	34.3	18.5
	Minimum	μ		1.9	6.6	4.3
VERTICAL BOW	Average	μ		36.6	56.8	36.1
	Maximum	μ		109.0	95.8	70.6
	Minimum	μ		11.5	30.09	16.1
HORIZONTAL BOW	Average	μ		15.7	53.4	24.1
	Maximum	μ		30.8	101.0	35.7
	Minimum	μ		6.5	8.7	5.5
VERTICAL CL BOW	Average	μ		91.7	113.3	60.3
	Maximum	μ		306.9	164.4	102.3
	Minimum	μ		15.9	81.3	31.6
HORIZONTAL CL BOW	Average	μ		29.2	109.7	48.7
	Maximum	μ		55.3	203.8	74.3
	Minimum	μ		8.6	19.4	14.9

TABLE 2
(continued)

WAFER THICKNESS CHARACTERIZATION SUMMARY

PARAMETER	TEST		2-5-04	2-5-06	2-6-01	2-6-02
SLICE	Diameter	(mm)	100	100	100	100
	Area	(cm^2)	78.5	78.5	78.5	78.5
THICKNESS	Average	μ	330.1		287.4	299.7
	Std. Dev.	μ	18.4		35.8	22.7
TOTAL VARIATION	Average	μ	61.1		56.9	25.4
	Std. Dev.	μ	13.9		23.7	17.8
STD. DEVIATION	Average	μ	23.0		21.9	12.7
	Std. Dev.	μ	5.2		9.5	7.6
VERTICAL TTV	Average	μ	90.3		75.4	
	Maximum	μ	122.7		162.5	
	Minimum	μ	50.6		30.2	
HORIZONTAL TTV	Average	μ	12.7		14.6	
	Maximum	μ	22.9		36.3	
	Minimum	μ	6.4		4.9	
VERTICAL BOW	Average	μ	119.5		31.9	
	Maximum	μ	142.3		68.0	
	Minimum	μ	46.8		12.8	
HORIZONTAL BOW	Average	μ	16.5		29.3	
	Maximum	μ	24.1		42.4	
	Minimum	μ	8.2		13.0	
VERTICAL CL BOW	Average	μ	274.0		80.4	
	Maximum	μ	344.1		129.0	
	Minimum	μ	95.9		28.9	
HORIZONTAL CL BOW	Average	μ	38.8		66.4	
	Maximum	μ	68.1		84.3	
	Minimum	μ	13.8		15.1	

TABLE 2
(continued)

WAFER THICKNESS CHARACTERIZATION SUMMARY

PARAMETER	TEST		2-6-03	2-6-04		
SLICE	Diameter	(mm)	100	100		
	Area	(cm^2)	78.5	78.5		
THICKNESS	Average	μ	273.6	267		
	Std. Dev.	μ	18.4	28.8		
TOTAL VARIATION	Average	μ	45.9	61.8		
	Std. Dev.	μ	22.5	21.1		
STD. DEVIATION	Average	μ	16.8	24.2		
	Std. Dev.	μ	9.1	9.5		
VERTICAL TTV	Average	μ	60.1	78.6		
	Maximum	μ	127.4	121.9		
	Minimum	μ	32.0	34.9		
HORIZONTAL TTV	Average	μ	7.8	13.6		
	Maximum	μ	20.4	27.7		
	Minimum	μ	2.2	4.0		
VERTICAL BOW	Average	μ	51.5	85.1		
	Maximum	μ	73.3	157.4		
	Minimum	μ	26.6	19.4		
HORIZONTAL BOW	Average	μ	18.4	21.0		
	Maximum	μ	38.9	47.3		
	Minimum	μ	7.2	2.5		
VERTICAL CL BOW	Average	μ	117.0	172.2		
	Maximum	μ	157.3	397.3		
	Minimum	μ	45.7	64.9		
HORIZONTAL CL BOW	Average	μ	40.7	40.9		
	Maximum	μ	70.8	93.1		
	Minimum	μ	19.6	7.0		

The results of this test were encouraging in terms of using potentially cheaper abrasive, but controlled cutting conditions were not achieved. Cause of the low yield must be established.

3.1.2 Light Mix Lubrizol: Test #2-3-06

Since Lubrizol 5985 oil had not performed well under the same conditions as the standard slurry oil, we decided to vary the abrasive mix. Feeling that Lubrizol may provide a higher effective mix at the cutting interface due to the higher suspension power and lower viscosity, we decided to reduce the amount of abrasive.

For this test, the mix was 0.24 kg/l (2 lb/gal) and conditions were standard (0.15 mm blades, 85 grams/blade loading). Efficiency, abrasion rate, and productivity were slightly low. Cutting time was longer than usual, and kerf loss was high. Yield was only 19%. Slice taper and bow were slightly high.

We felt that since a slight improvement over previous tests was noted in the early stages of this test, we were going in the right direction.

3.1.3 Mixed Abrasives: Test #2-3-07

Continuing the effort to lower the price of abrasive by using a broader spectrum of particle sizes, a slicing test was made using equal parts of #600, #800 and #1000 grits. Cutting force, cutting speed, ingot size, and suspension oil were standard. 0.15 mm x 6.35 mm blades with 0.40 mm spacers were used. An error was made in slurry mixing: only half the desired amount of abrasive was mixed, so the overall abrasive mix was 0.18 kg/l.

Cutting time was good, 23.2 hours. However, severe slice breakage occurred and the yield was only 3%. The blades, again, showed anomalous side wear, up to 1/3 the total thickness. The appearance of side wear may indicate that a wafer breakage is caused by a machine problem, although no measurements have supported this.

3.1.4 Mixed Abrasives: Test #2-3-08

In an attempt to reduce kerf loss and abrasive cost, a standard condition run was made using equal parts of #800, #1000 and #1200 grit abrasive.

Again, yield was very low (11%). Cutting time was long (about 44 hours) as before with #800 grit slurry. Kerf loss was slightly reduced: bow and taper were somewhat large. The mixture of #800 and smaller abrasives does not seem to offer any improvement over #800 alone.

3.1.5 Light Mix Lubrizol: Test #2-3-09

Continuing the trend of Test #2-3-06, a run was made at a mix of 0.12 kg/l (1 lb/gal). All other conditions were standard.

Kerf loss was reduced. Slice taper was increased slightly and slice bow increased significantly. All other measurements were comparable to Test #2-3-06. Yield was only 12%.

The low yield and high taper and bow were partly a result of blade breakage and wear. The blades were worn on the side by approximately 1/3 the thickness. The ratio of the number of blades worn on one side to the number worn on the other side was 10:1, indicated some asymmetry in the cutting process. This amount of wear

is unprecedented in cutting any material in any condition. We cannot yet give a good reason for this wear. However, the early stages of cutting appeared quite good. It is possible that the abrasive was limiting the slurry life at the end of the cut. However, it appears that light mix was the correct approach for standard Lubrizol.

3.1.6 Light Mix Lubrizol: Test #2-3-10

In order to find the point at which a Lubrizol slurry has too little abrasive, and to investigate the side wear problem, a test was run with a 0.06 kg/l (½ lb/gal) mix. Yield was so low (4%) that only cutting time could be measured. The cutting time increased significantly. This has always been a good indication that the total amount of abrasive was too little; thus, it seems that a heavier mix is necessary with Lubrizol.

The high side wear occurred again. Measurements were made during the cut with the following results. At ¼ of the cut depth, side wear could not be measured; at ½ the cut depth, side wear was 0.05 times the blade thickness; at the end of the cut the side wear was 1/3 of the blade thickness.

These results indicate that the side wear is due to some effect which changes during a cut, perhaps the geometric changes due to the round cross-section of the ingot or abrasive breakdown due to the small amount of abrasive used. Although Lubrizol with a light mix is economically attractive, we cannot use it until we resolve the side wear question. It still remained that the early cutting was better controlled and breakage occurred after 1/3 of the ingot has been cut.

3.2 Cell Fabrication: Test #2-4-04

Three hundred 0.15 x 6.4 mm blades with .41 mm spacers were used to cut a 10 cm silicon ingot for surface preparation and cell fabrication studies. Cutting time was 28 hours, but yield was only 29%. Slice thickness was .322 mm and kerf loss was 0.237 mm. Slice breakage during the cutting process and poor yield with thin slices continues to plague this phase of the program.

3.3 Miscellaneous Slicing Techniques

3.3.1 Upside Down Cutting: Test #2-5-03

To determine the characteristics of slurry ingress to the blades during MS slicing, a special work holding fixture was installed on a standard Varian 686 MS saw to allow "upside-down" cutting of a 10 cm silicon ingot. 150 0.20 x 6.4 mm blades and 0.41 mm spacers were used with 113 grams of blade load. 0.48 kg/liter of #600 SiC was used as a slurry with "pulse-type" application to either side of the ingot.

Cutting time was 26.1 hours, yield was 100% and the bow and taper of the 10 cm slices was 36 and 44 microns respectively. Indeed the cutting process proceeded well in this mode and the slice accuracy was the best seen to date.

The work-holder tended to loosen and rock slightly at the end of each bladehead stroke due to the direction of loading in this cutting mode. For this reason a new test was scheduled to eliminate the rocking motion which may have cushioned the cutting shock to wafers and been responsible for the improvements noted.

3.3.2 Constant Pressure Cutting: Test #2-5-04

It was assumed that the cutting pressure at the blade/silicon interface was important to controlled abrasion and that variations in pressure due to ingot cross-section (at constant load) might cause some of the bow/taper variations seen in MS slices. Cutting force was varied to maintain constant pressure with the maximum load being 113 grams per blade. 136 0.15 mm blades and 0.41 mm spacers were used. In order to suppress wafer fracture, a thin coating of epoxy was used on the perimeter of the ingot. The epoxy slowed the cut so severely during the early and late portion of the test that the overall slicing time was 63 hours. Yield was 71% and the edge chipping seen in the past did not occur. The coating disturbs the cutting process so severely, however, that an alternate will be sought. Wafer accuracy in the vertical direction was degraded, but in the horizontal direction, it was greatly improved.

3.3.3 Upside Down Cutting: Test #2-5-06

A second upside down cut was run to isolate the effect of the upside down mode from that of the rocking work-holder experienced in test #2-5-03. A rigid work-piece mount was used and cutting went very well until half way through the ingot when the workpiece broke loose from the submount. This experience was sufficient to show that the reversal of gravity on the action of slurry was the useful improvement with this technique.

3.4 Alignment Device Tests

This series tests a device designed to improve the alignment of a set of multiple blades. The concept considers the possibility of blade misalignment being the limiting condition for thin wafer slicing and the use of thin blades in MS slicing.

3.4.1 Alignment Device: Test #2-6-01

The alignment device was installed onto a package with 150 0.15 mm blades and 0.35 mm spacers. The installation was facilitated by positioning the rack gears into engagement with the blades prior to tensioning. Both end blades were parallel within 2-3μ, a distinct improvement over normal blade packages. By adjusting rack gear positions, a vertical runout of ±3 microns was obtained in the four measurable points at the corners of the blade package. Slurry was a standard mix of 0.36 kg/liter. Total cutting time was 23 hours faster than normal, however, the first half of the ingot was cut with a blade force of 127 grams, rather than 85 grams. Total wafer yield was 81% (120 of 149). Slice thickness averaged 287 microns with a kerf loss of 221 microns. Wafer accuracy was improved over the best cutting accuracy obtained with 0.15 mm blades. However, the difference was not significant to herald success of the alignment device at this point.

3.4.2 Alignment Device: Test #2-6-02

A second test of the alignment device was performed using a different installation technique. The blade package was first measured to assure that its width, after compression, could match the exact spacing of the rack gears. Opposing pairs of spacers were replaced with oversized spacers to

achieve this condition. The package was fully tensioned, and then the width was adjusted by modulating the side compression. The rack gears were easily engaged at this point. All preliminary alignment went as before except that vertical alignment of one side of the package was off vertical by 75-125μ. This was averaged over that end of the package, but the variation was not correctable since one gear seemed to be longer than the other. The rest was run with 150 0.15 mm blades, 0.35 mm spacers and 85 grams of blade load with a slurry mix of 0.24 kg/liter.

Cutting appeared to go well, but the ingot broke loose from the submount after half of the ingot had been cut. Measurements of the broken wafer pieces indicated 200 microns of kerf loss and 300 micron thick slices. Bow and taper measurements were not meaningful, but the surface profiles were very impressive. Further testing, following this installation technique, will be pursued. Four new sets of gears are expected soon.

3.4.3 Alignment Device: Tests #2-6-03 and #2-6-04

Two cutting tests were performed using the multiple blade alignment device with identical conditions (0.15 x 6.4 mm blades, 0.36 mm spacers, 85 grams/blade loading, 0.36 kg/liter mix of #600 SiC abrasive).

In the first, a set of gears used many times was installed. Blade parallelism was within 3 microns, but vertical alignment was, as in test #2-6-02, out by 60 microns at one end of the pack. Cutting time was 28.3 hours and yield was 53% (10 cm slices). Taper and bow were 50-60 microns average in the vertical direction. Slice thickness was .273 mm with .235 mm kerf loss.

A new set of rack gears was installed for test #2-6-04. Vertical alignment was only within 20-30 microns, but improved over previous tests. Cutting time was 32.3 hours and 66% yield resulted with 10 cm slices. Slice thickness was .267 mm and kerf loss was .241 mm. Bow and taper were not improved (80 microns average).

Since only minor improvements in slice accuracy have resulted from tests with the alignment device, the next step in its test process will be to test it using 300 blades (150 have been used previously) and then with 0.10 mm blades which have suffered from fatigue induced breakage in the past.

4.0 DISCUSSION

4.1 Cell Fabrication

A set of 20 silicon wafers cut on the MS saw was sent to Solar Power Corp. for fabrication into solar cells in their standard commercial processing line. The slices were 10 cm diameter with a nominal thickness of 300μ. Of the twenty wafers, only 1 survived the complete processing sequence. One was broken in shipment, 7 broke during the boron diffusion step and 11 others broke during other process steps. The remaining cell produced V_{oc} of 0.55V, I_{sc} of 1.68A, maximum power (P max) of 0.67W and a fill factor of 0.725 at 100 mw/cm^2 illumination and 28°C. This represents an efficiency based on full wafer area of 8.53%, (8.97% based on 9.75 cm diameter applied cell area). Since the potting compound acts as part of the AR coating system for Solar Power's cells, the performance cited above is expected to improve by 10% in a completed panel. Therefore, the efficiency of this cell may be characterized as 9.4% based on the 10 cm wafer or 9.9% based on the size of the active cell applied.

4.2 Lab Saw

Because of the complete change of design necessary in the laboratory saw, the fabrication of that unit will be delayed the next quarter. The small number of blades requires a new concept of feed mechanism to apply the small loads required. The blades will be adjustable from 10 inches to 22.5 inches in length, requiring a new, longer bladehead, a longer waybed and an adjustable position drive system. The bladehead has been completed during this reporting period. The waybed was ordered in September and delivery was slow. These two have been subcontracted for machine work, and grinding and expected delivery of mid-December was not met. Drawings for the lab saw are shown in Appendix I in the S-2000 series.

4.3 Prototype Large Capacity MS Saw

Basic mechanical design for the 1000 blade capacity multiblade slurry wafering saw is complete and fabrication began during this quarter. The machine is designed to slice a 45 cm long silicon ingot with up to 1000 blades of 0.15 x 12.7 mm cross-section. The blade tensioning capacity is 270,000 kg (600,000 lb). The basic design concept is a modification of the underslung reciprocating workholder carriage described in the previous report. Gravity is utilized to protect sliding members from the abrasive slurry. Drawings for the prototype are shown in Appendix I in the S-1000 series.

The bladehead tensioning is accomplished with two clamping elements spread apart by a pair of closing scissors. Design for the system indicates that a torque of 35 kg-m (250 ft. lbs) must be applied to each of two scissor closing bolts in order to apply 270,000 kg of tensioning force. Final bladehead design will be completed soon after the first of the year.

4.4 Investigation of Suspension Media

We are investigating the possibilities of using various oil or water bases suspension media for slurry sawing. To date, most of the research has concentrated on oil based suspensions, since few water based suspensions are manufactured and we do not know the optimum characteristics of such media. (Manufacturers of water based media are being contacted.) We are currently working with our standard suspension oil (PC oil) and a new oil manufactured by the Lubrizol Corporation (Lubrizol 5985).

Attempts to use 5985 have been disappointing. The best results so far have been obtained using 1/3 the amount of abrasive normally used in PC oil (0.36 kg/l). A portion of the wafer breakage problems may be traced to machine problems (poor yield in standard cutting tests), but this condition is yet to be certainly corrected. It is possible that some wafer breakage was due to abrasive failure, abrasive settling, or some other mode of failure, all due to the small amount of abrasive in the system. When we are sure the machine faults have been corrected, we will retest 5985 with a low abrasive mix: this combination is attractive because the cost approaches the $\$3.00/m^2$ slurry cost goal.

In the meantime, we are carrying out a more structured investigation of the two suspension oils. The first steps have been consideration of important differences and characterization of the two oils.

4.4.1 Comparison of 5985 and PC

The major differences between 5985 and PC are:

1. Different suspension power (5985 holds abrasive in suspension longer).
2. Viscosity (5985 is less viscous).
3. Suspension method (5985 uses a dissolved polymer, PC uses colloidal clay platelets).

We feel that the suspension method does not affect the cutting process significantly (although it may affect reclamation).

It seems likely that the suspension power and/or viscosity affect the cutting process through abrasive transport. The cutting process is controlled not by the actual abrasive mix but rather by the "effective mix" (i.e., a measure of the number of active particles at the cutting interface). Greater suspension power and/or lower viscosity might well increase the effective mix by transporting particles to the cutting interface more efficiently.

The first step in our systematic investigation must be to identify the important variables. In order to demonstrate that viscosity and/or suspension power are the important variables, we intend to mix mineral oil with 5985 or the 5985 polymer additive to match PC as closely as possible. If this mixture behaves like PC, that will show that only viscosity and/or suspension power are important. Once we have identified the important variables, we can vary them systematically and independently to ascertain their effects and relative importance.

4.4.2 Characterization of Oils

The viscosities of both oils were measured using a Brookfield LVF viscometer with the #2 cylindrical spindle. The samples were 550 ml of the test fluid in a 600 ml Griffin low form beaker (kImax #14000). The spindle-beaker combination were calibrated with silicone oil viscosity standards (92 cps $\pm 1\%$ and 505 cps $\pm 1\%$). The temperature was 25° ± 1°C in all tests. The results are presented in Figure 1 and discussed below.

Suspension power was measured by static settling tests. 50 g of PC, 5985, or 5985 cut with 130 cps mineral oil were mixed with 20.85 g of #600 SiC (corresponding to a standard PC mix: note that the specific gravity of all the oils ranges from 0.89 to 0.91). These mixtures were shaken and allowed to stand until significant settling took place.

PC oil is a thixotropic fluid: the viscosity depends on both strain rate and history. The viscosity decreases asymptotically with time at a given strain rate. This is not surprising, since the clay platelets probably line up as shearing proceeds. The viscosities in Figure 1 are asymptotic viscosities.

PC settles by loss of suspension power. Both the platelets and abrasive settle, so that a clear oil area forms at the top, with a homogeneous mixture of abrasive and platelets below.

Lubrizol 5985 is a psuedo-plastic fluid (on the time scale investigated): the viscosity depends only on strain rate. Only the abrasive settles out: larger abrasive particles settle faster, so a three-layer structure forms: a thin layer of oil and suspension agent above a region of oil, suspension agent, and fine abrasive particles above a cake of fully settled particles.

It is essentially impossible to match 5985 and PC by diluting 5085. Consideration of Figure 1 shows that the viscosities can be matched at all strain rates by diluting 5985 with carefully tailored psuedo-plastic fluid (a difficult job !)*. We do not know if the thixotropic nature of PC is important. However, it seems that a reasonable viscosity

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* The strain rate in MS slicing varies during each stroke from 0 to approximately 10^5 sec^{-1}, with an average value of 5×10^4 sec^{-1}.

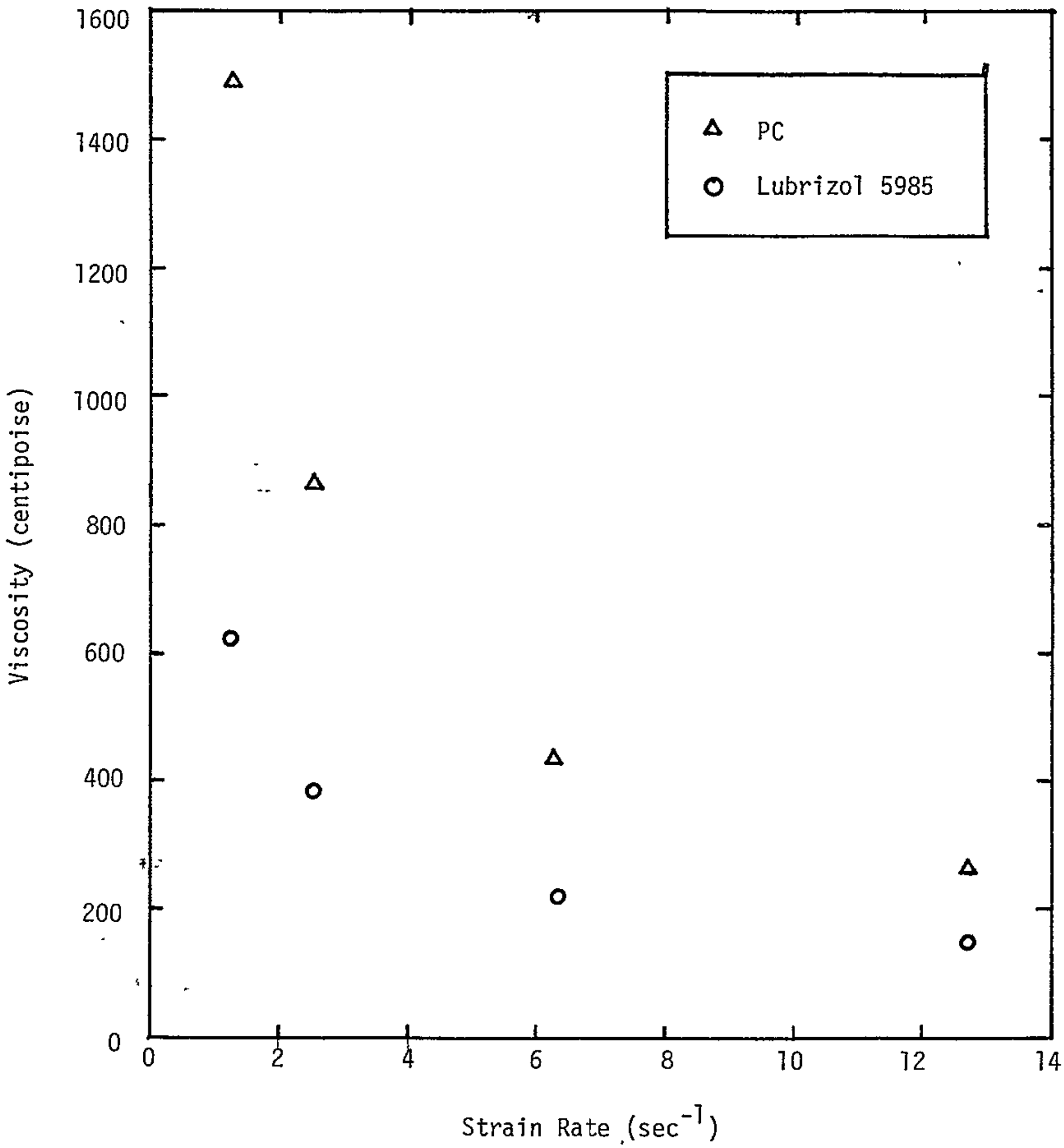


FIGURE 1 VISCOSITY OF SUSPENSION OILS

match may be obtained by mixing 5985 with a mineral oil chosen to give a viscosity of around 250 cps at 12.5 sec^{-1}.

Matching suspension power is also difficult because 5985 forms a cake at the bottom and PC does not. On the basis of clear top area, it appears that a mixture of 40-45% 5985 matches PC best.

4.5 Slurry Reclamation

Earlier reports stated that the failure mechanism of slurry appears to be debris accumulation. We have been investigating the possibilities of several methods of separating the components of used slurry for reuse. In the last quarter, sufficiently encouraging replies have been received from manufacturers so that we feel able to discuss possible mechanisms of reclamation.

There are many problems which make the separation of slurry components difficult. The abrasive nature of the slurry could lead to excessive separating machine wear. The large solid volume could lead to clogging. The oil is designed to keep the solids in suspension.

We currently envision a two-stage separation process. In the first stage, the majority of the oil would be removed, leaving a Si/SiC sludge. If the oil were PC, the separated oil would probably have little or no suspension power since the clay platelets would be left in the sludge. If the oil were LZ 5985 or an equivalent, the separated oil would probably still contain dissolved polymer and the suspension characteristics would be at worst slightly degraded. With the suspension oil removed, separation of silicon and silicon carbide would be easily done in the second stage.

The most promising oil separation device is the Mott Inertial Filter, manufactured by Mott Metallurgical Corporation, Farmington, CT. The filtration element consists of a sintered stainless steel tube, sintered under little or no pressure so the tube is porous. The tube is open at both ends, and the liquid to be filtered is pumped around a closed loop which includes the tube. As the liquid passes through the tube, the cross-sectional pressure gradient and inertial effects concentrate the solids in the center of the tube, while the liquid passes through the walls. Filtrate flow ranges from 0.4 to 8 l/min depending on many factors. Particles down to 0.1μm are filtered out. The element does not clog, and wear is negligible or not present. The machine is relatively low cost (approx. $3000 for the machine and $500 for the filter element). We will test this system with both PC and 5985 based slurries.

Once the oil is removed, the Si/SiC separation step would be relatively easy. The SiC particles are about 10 times larger and 50% denser than the Si particles. Separation should thus be possible either by static settling (in a liquid in which Si floats and SiC sinks) or elutriation (in which an upward flowing stream of liquid lifts lighter and smaller particles from a liquid). Both systems will be tested with the sludge obtained from filter tests.

5.0 CONCLUSIONS AND RECOMMENDATIONS

1. Slice breakage from fracture resulting from the wafering process reduces yield in the case of fully propagated cracks and limits the production of solar cells from thin 10 cm silicon slices. This problem has not been resolved.

2. Mixtures of abrasive sizes and different slurry oils do not give suitable cutting performance with the current approach to MS slicing.

3. A scissor type blade tensioning system has the design potential to reduce operator setup time with a larger capacity MS wafering saw.

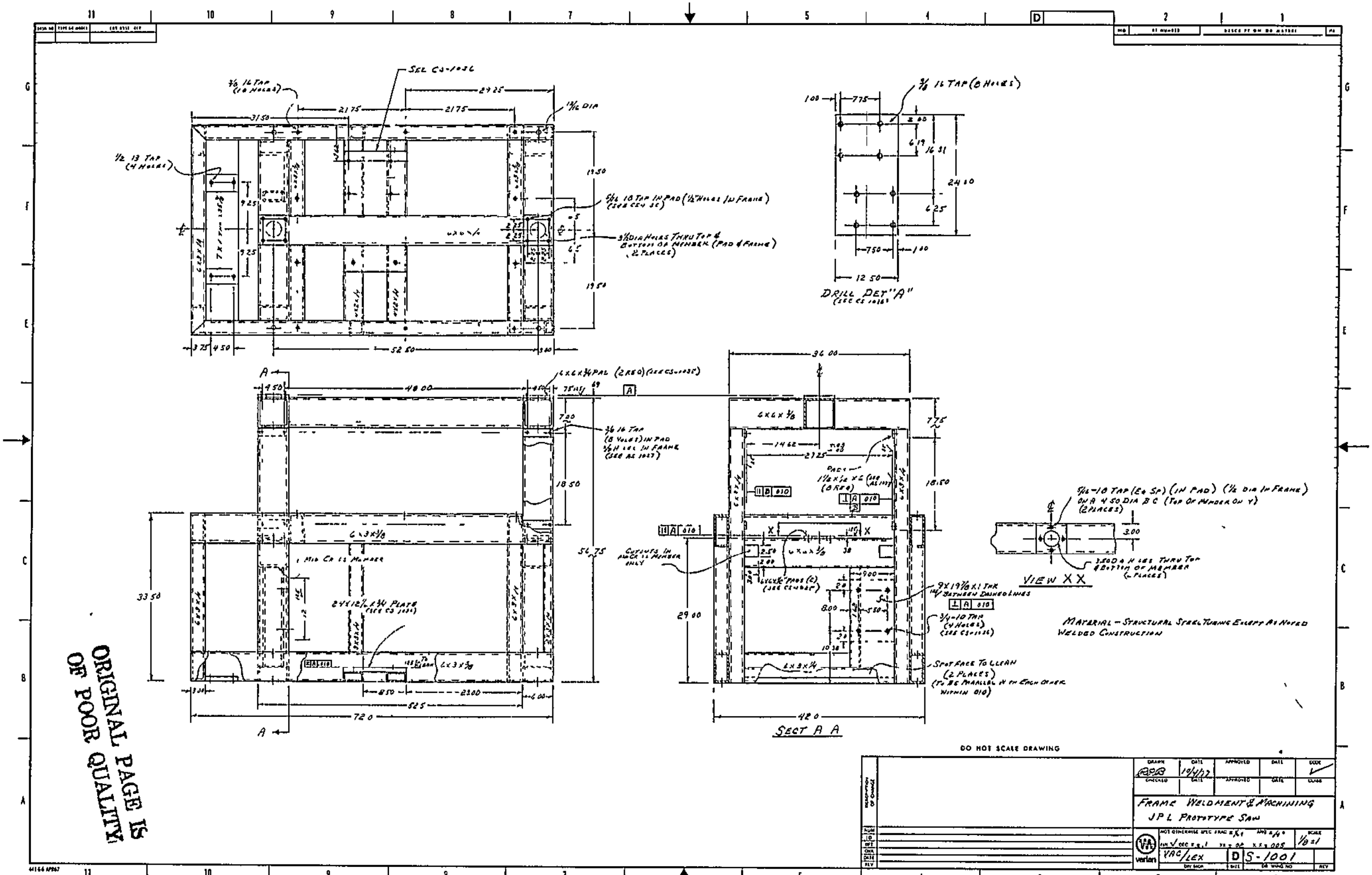
6.0 PLANS

Plans for the next quarter include:

- Complete lab saw
- Complete final design of large scale prototype.
- Fabricate low cost oil of characteristics similar to present oil. Test in MS slicing.
- Prepare SAMICS anaylsis of MS slicing.
- Test alignment device with 300 0.15 mm blades, and with 0.10 mm blades.
- Complete thorough etching studies with 10 cm and 2x2 cm MS silicon wafers. Begin cell fabrication.
- Test blade hardness variations.

APPENDIX I

Engineering Drawings and Sketches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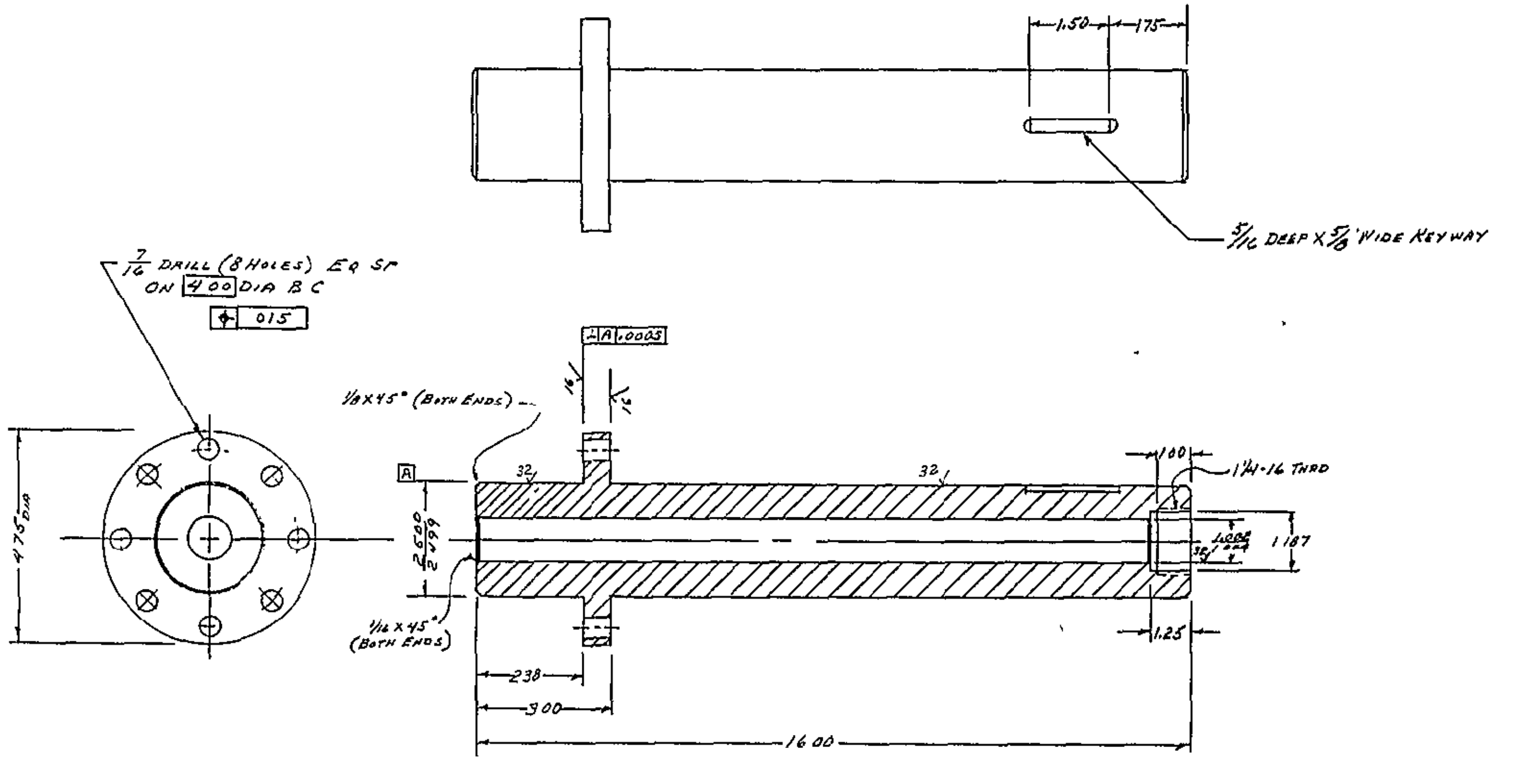

NOTE- ALL DIAMETERS TO BE CONCENTRIC WITHIN .001 T I R.

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FLYWHEEL SHAFT
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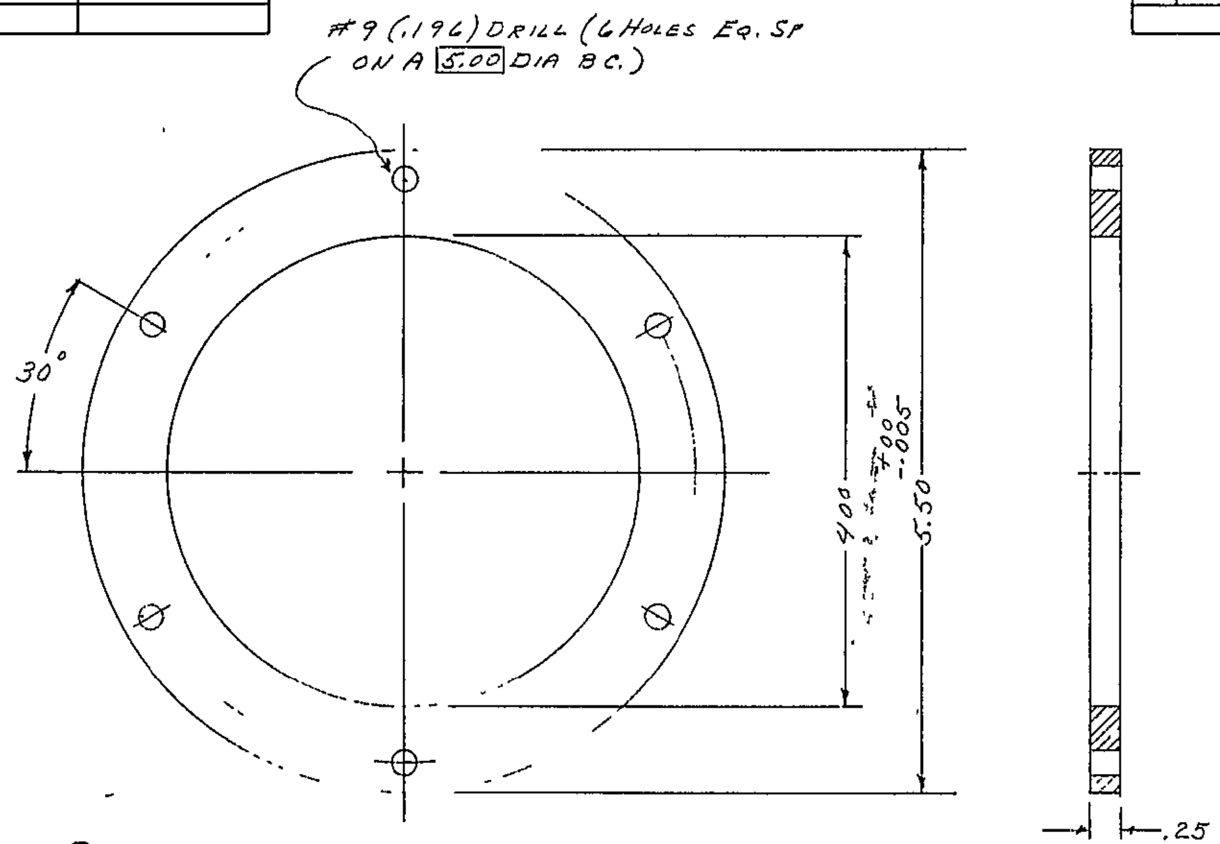

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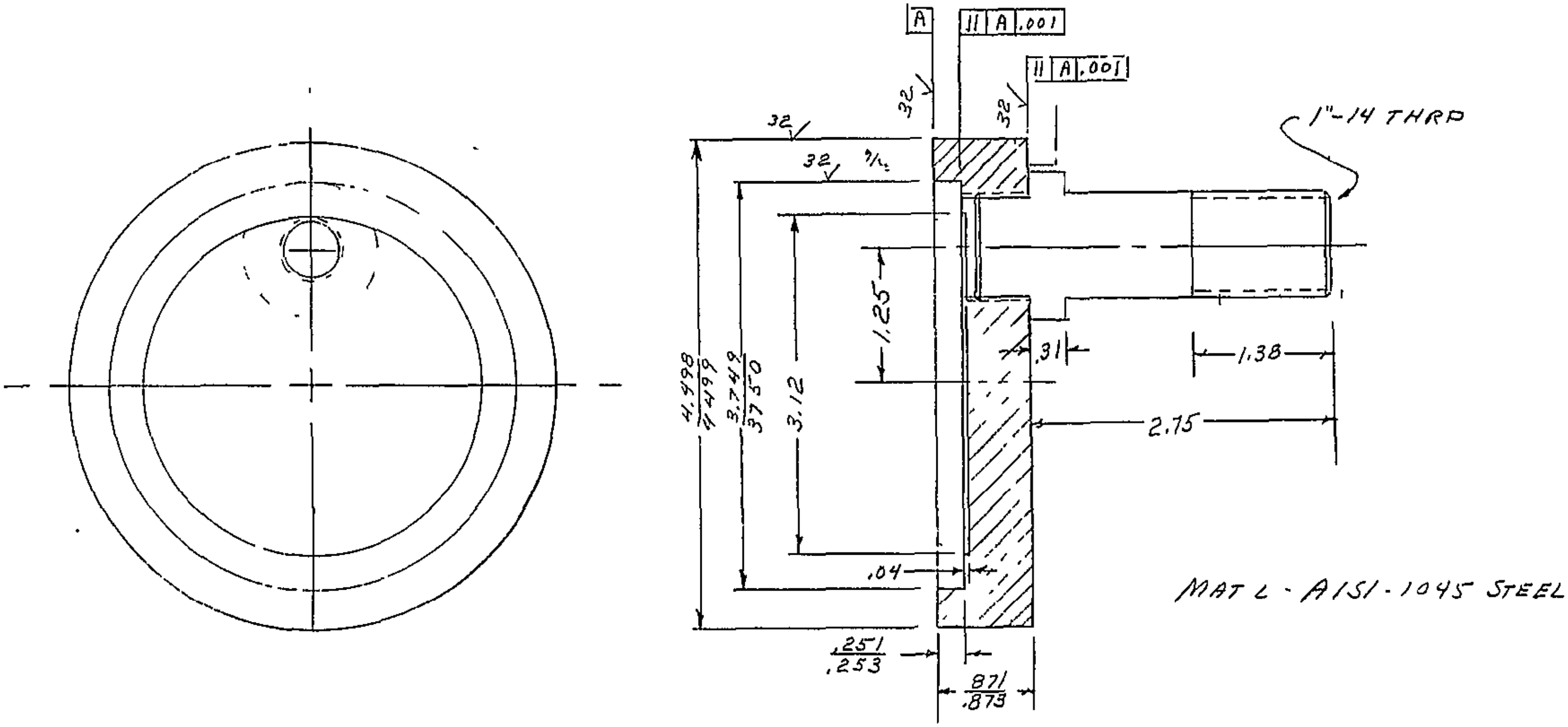

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ECCENTRIC HUB FOR FLYWHEEL
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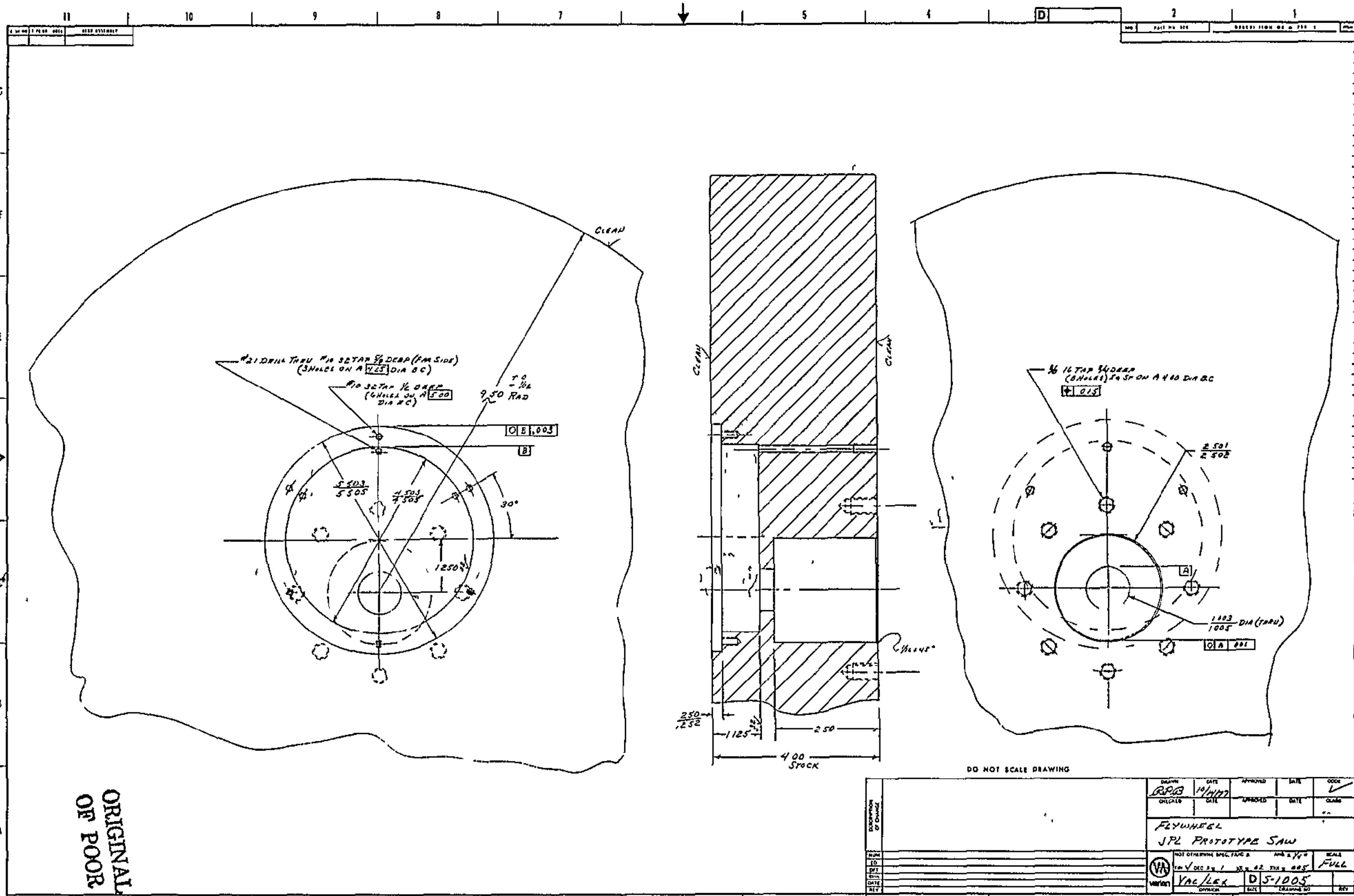

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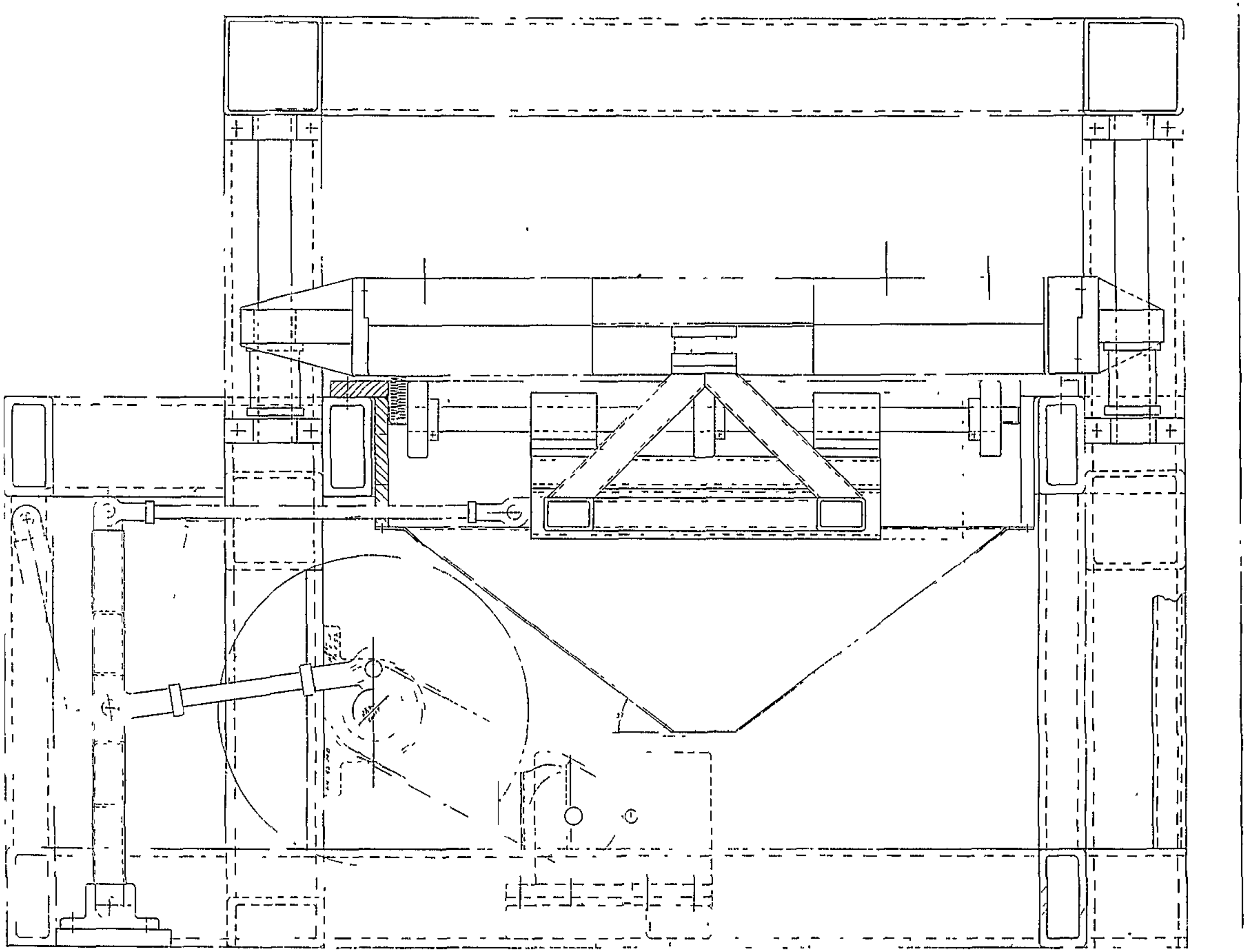

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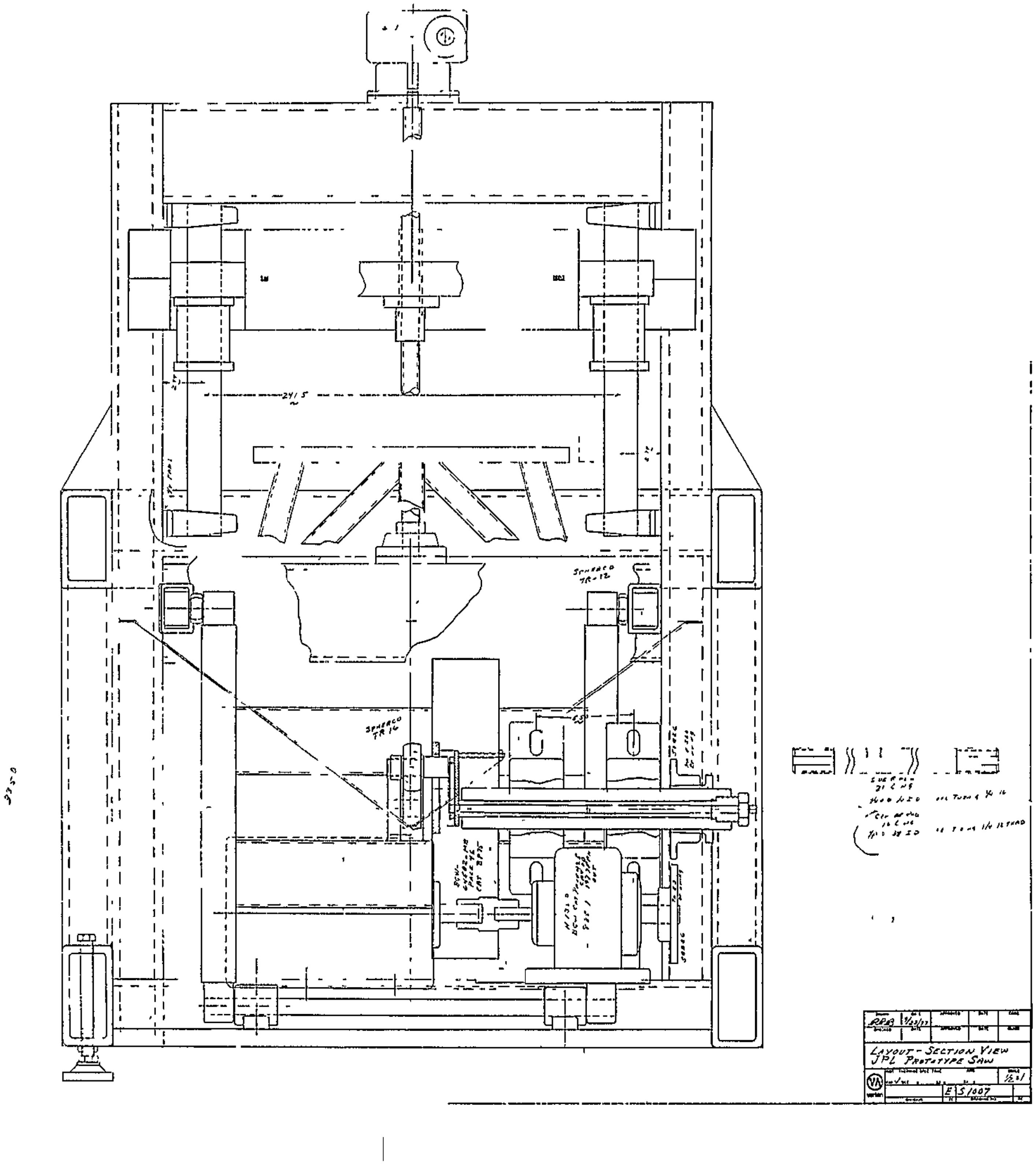
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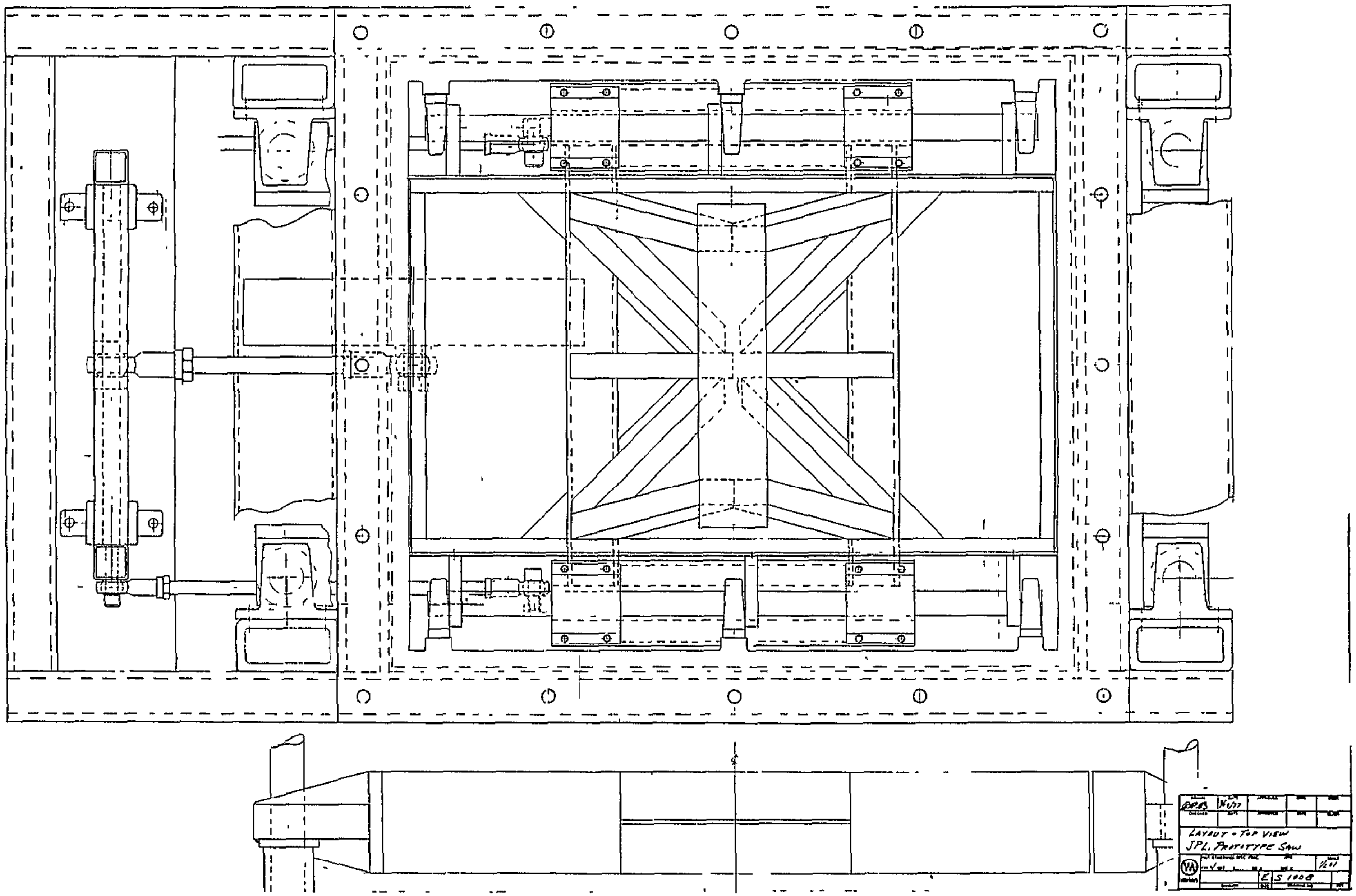

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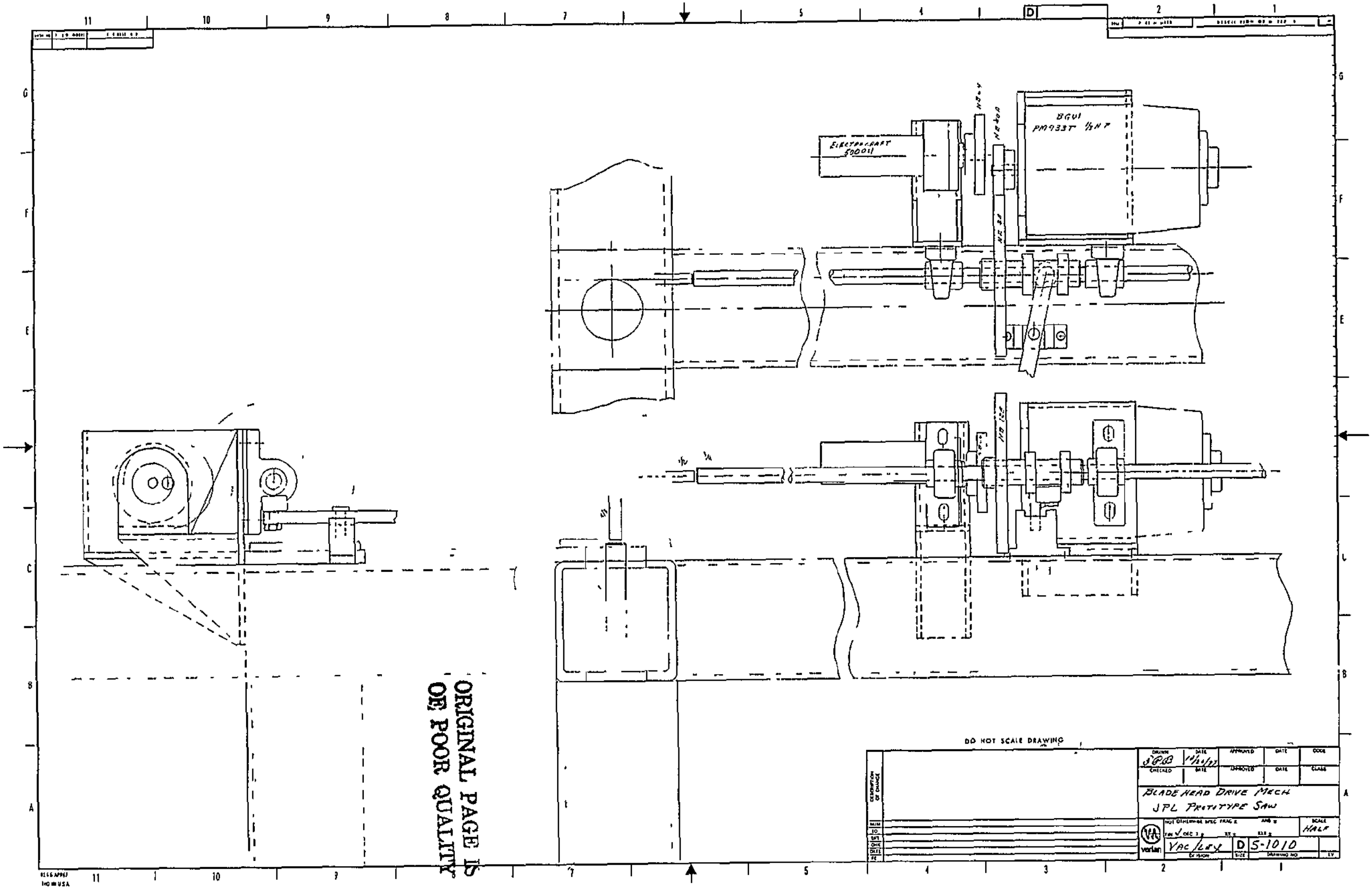
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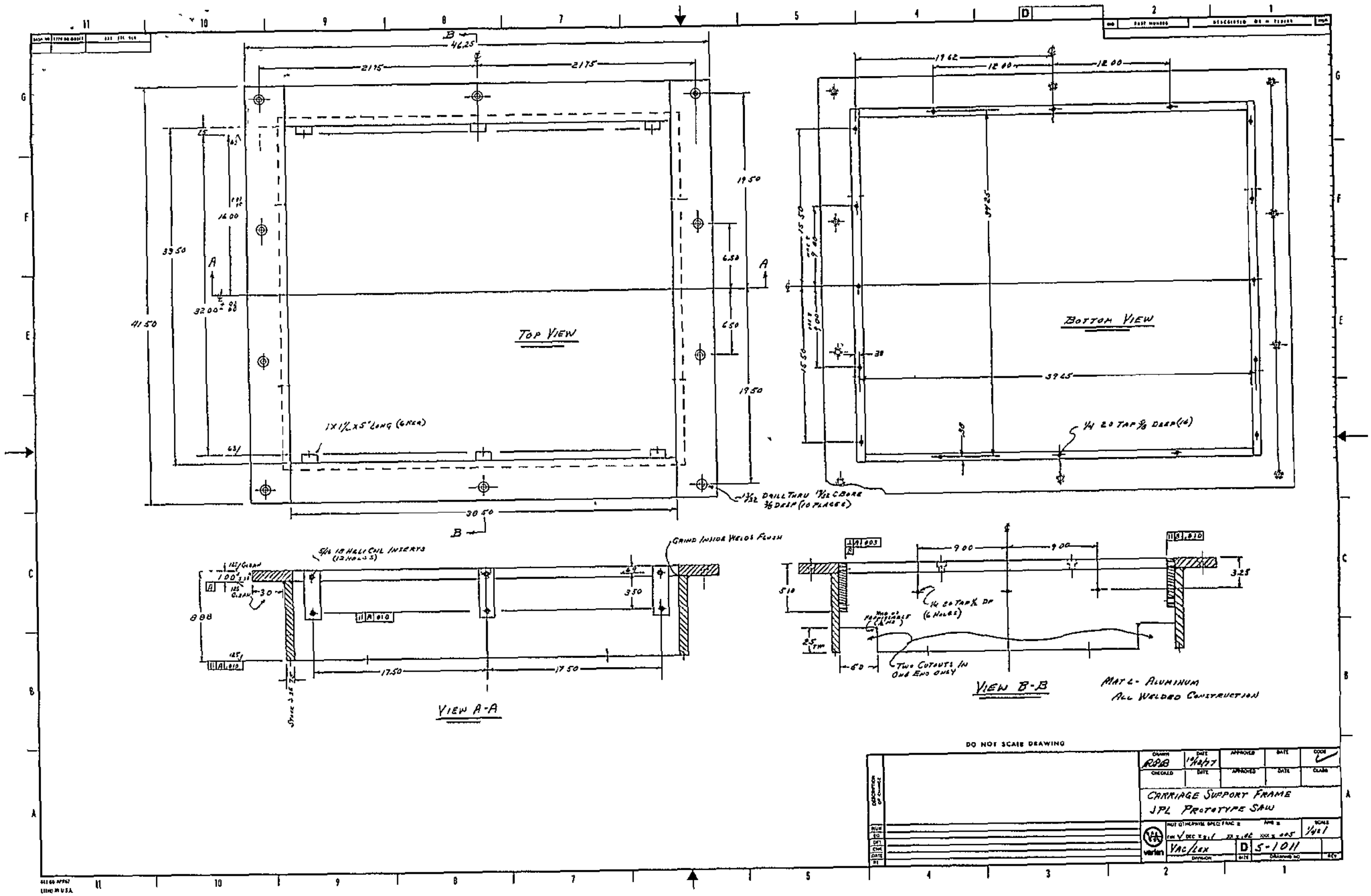
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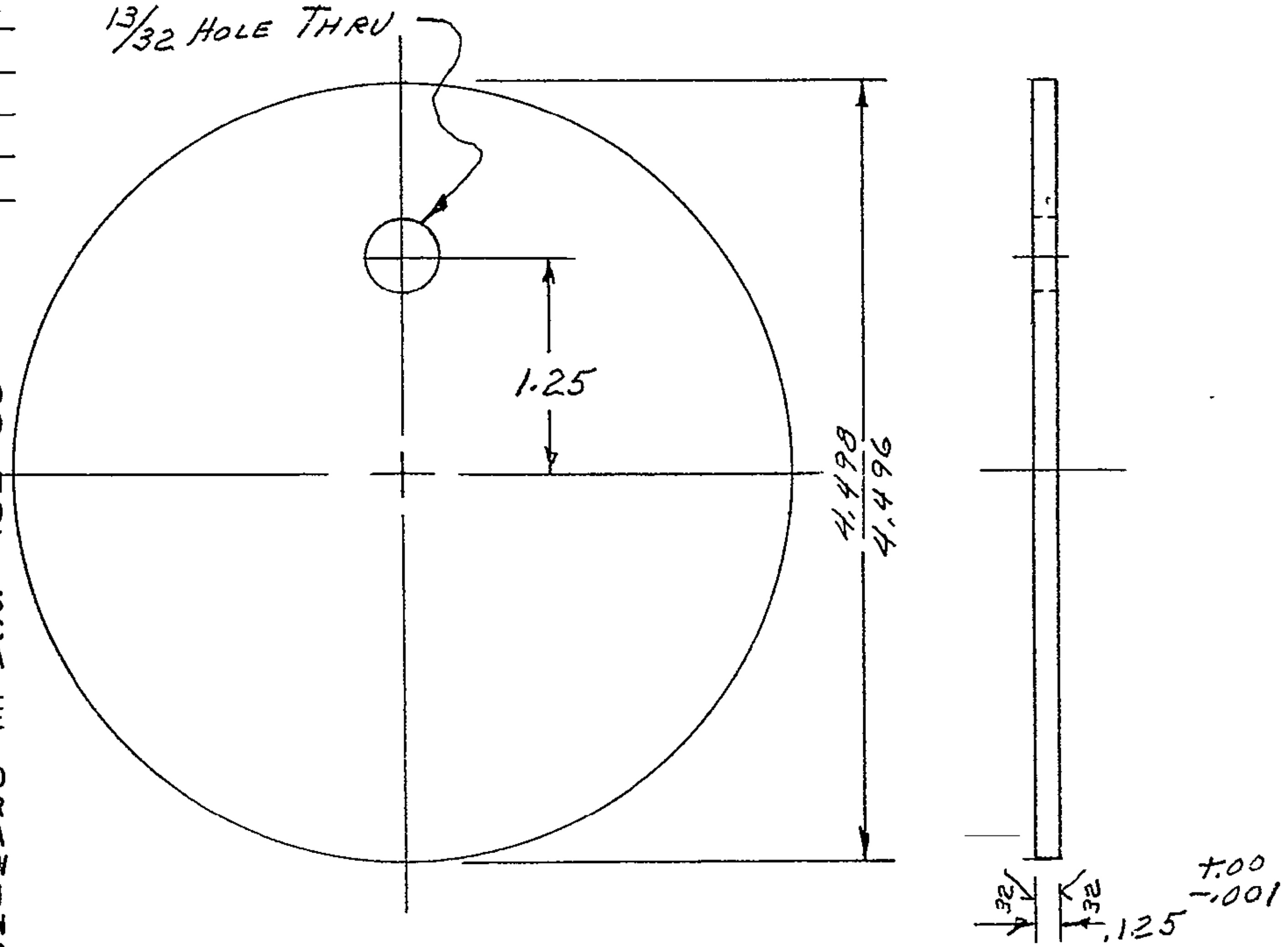

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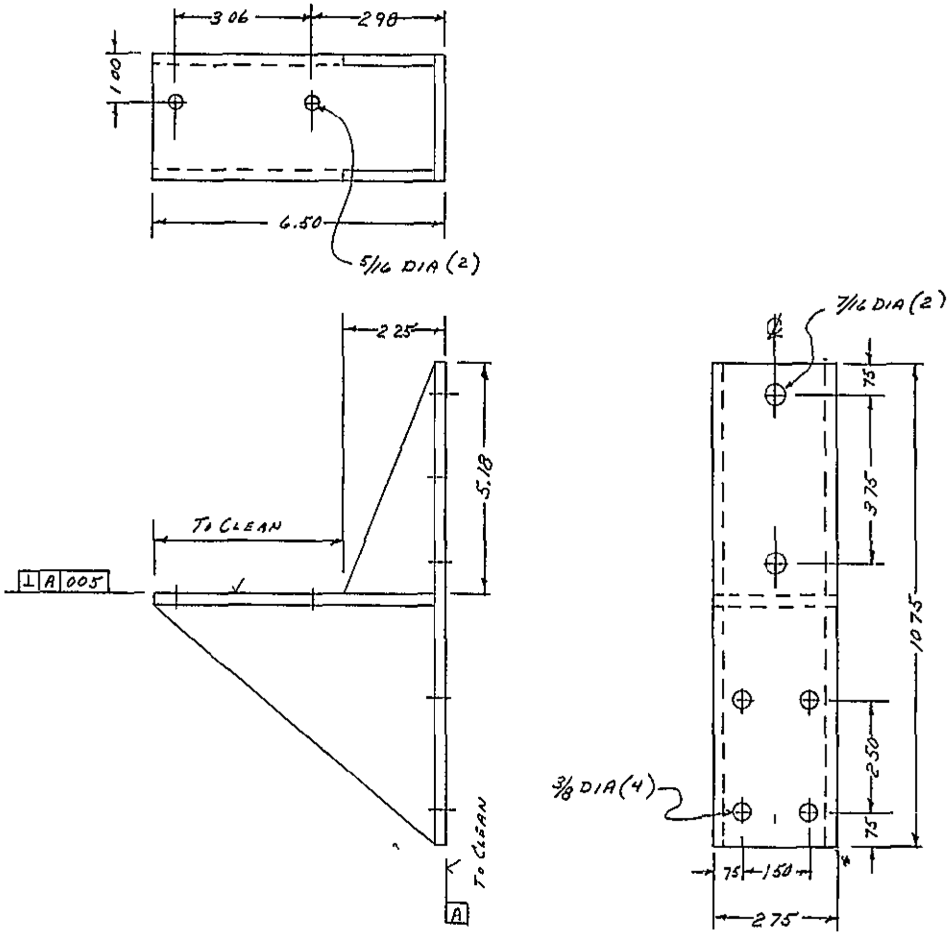

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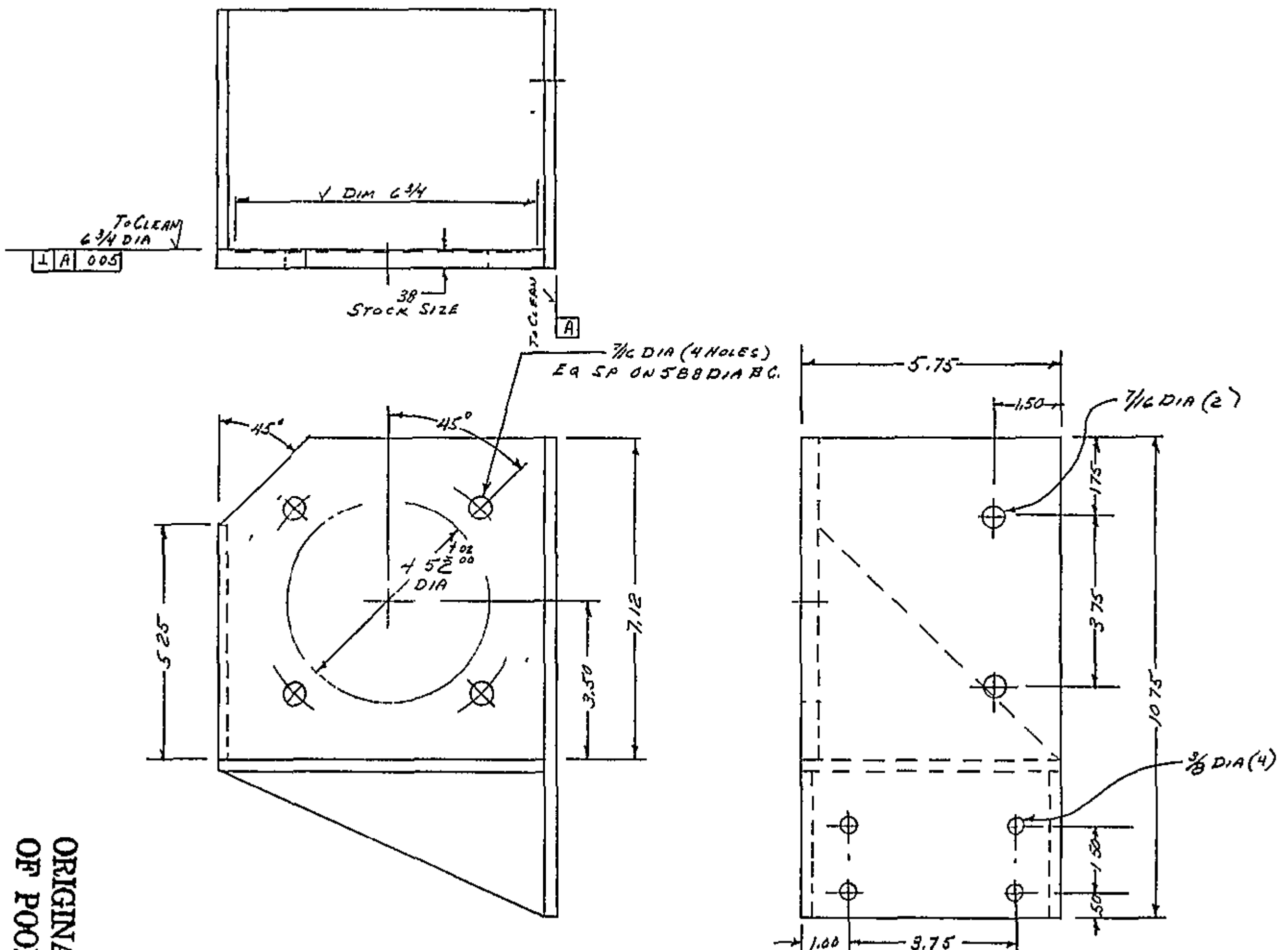

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BRACKET - HIGH SPEED MOTOR
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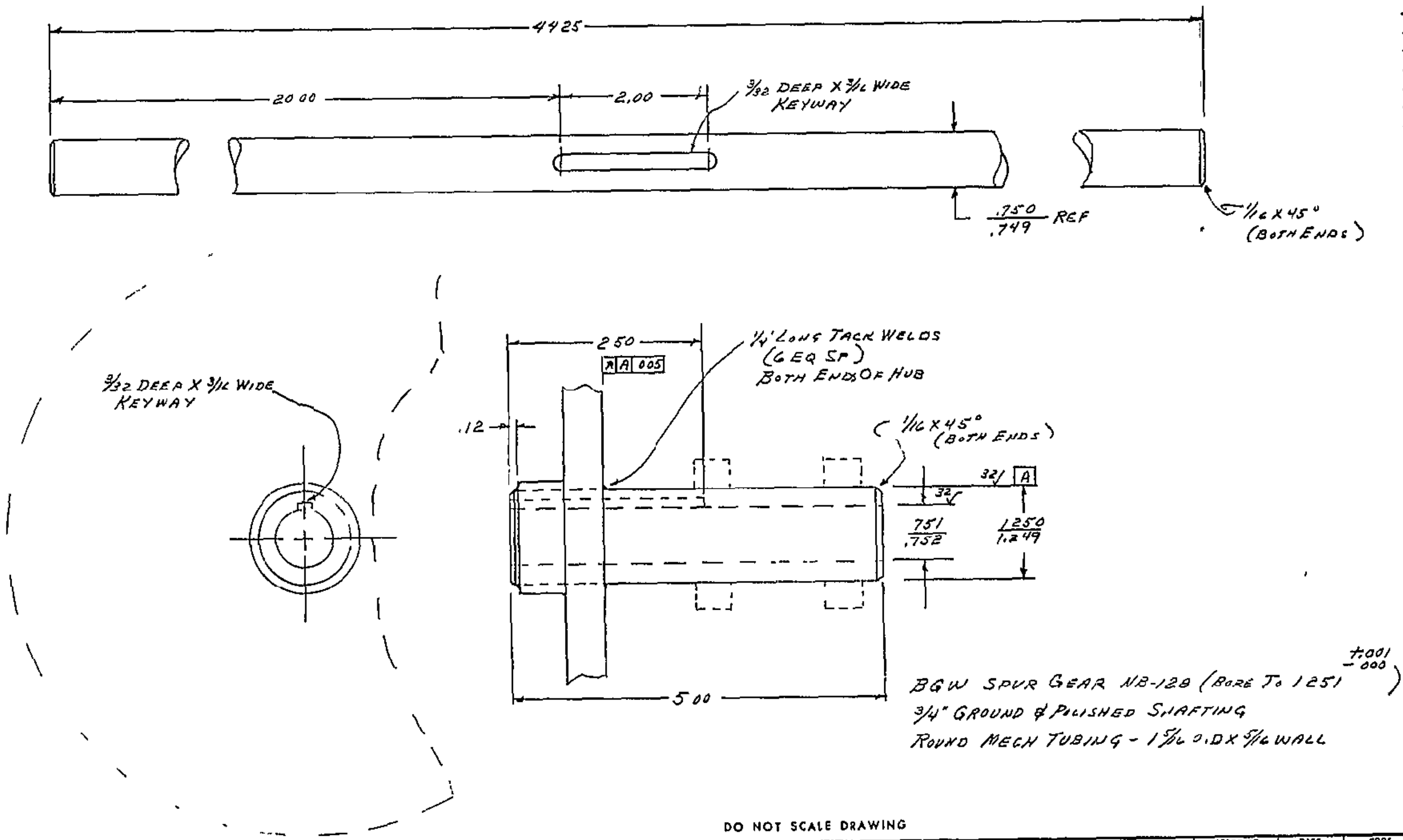

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BLADEHEAD DRIVE SHAFT
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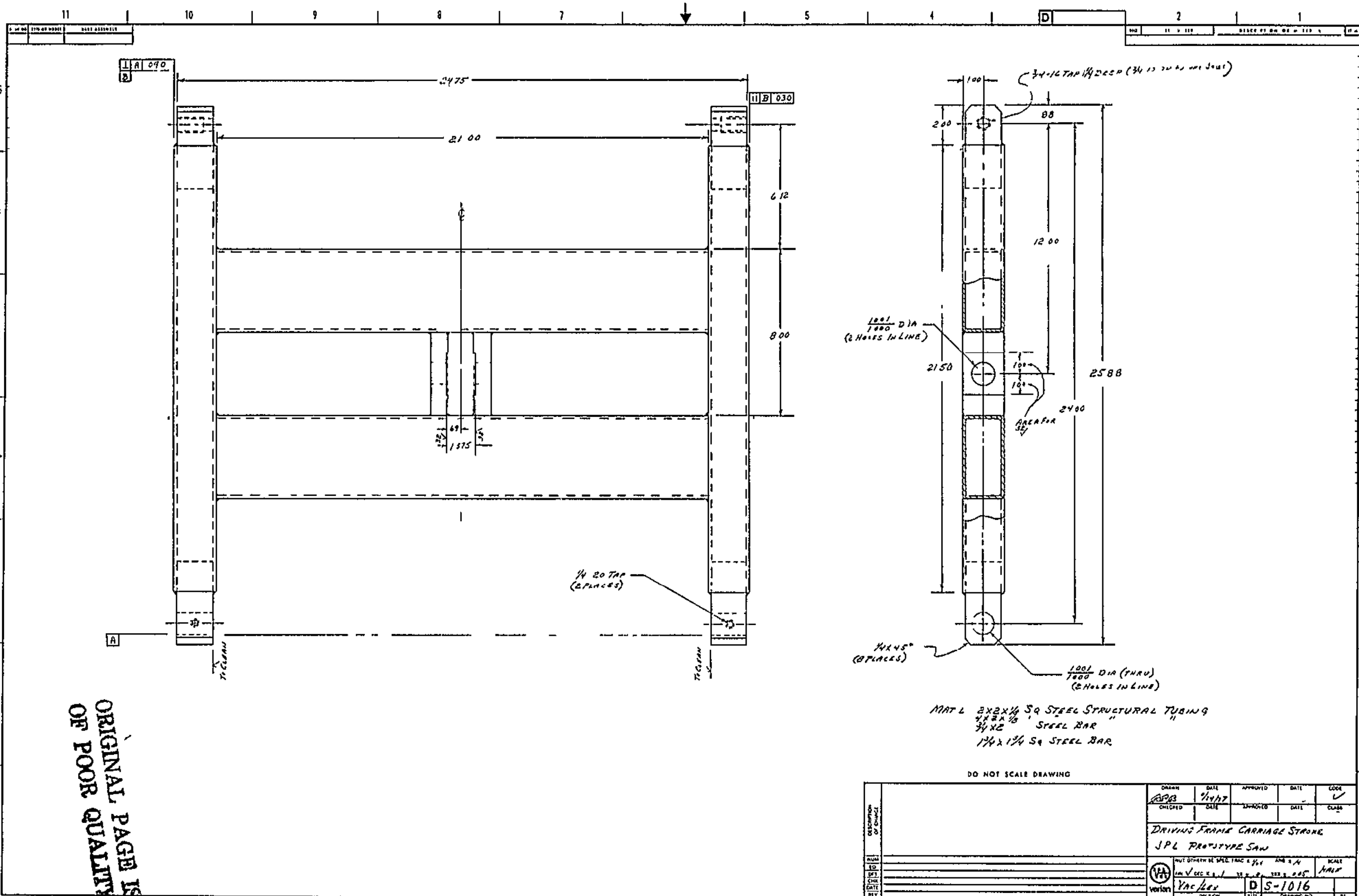

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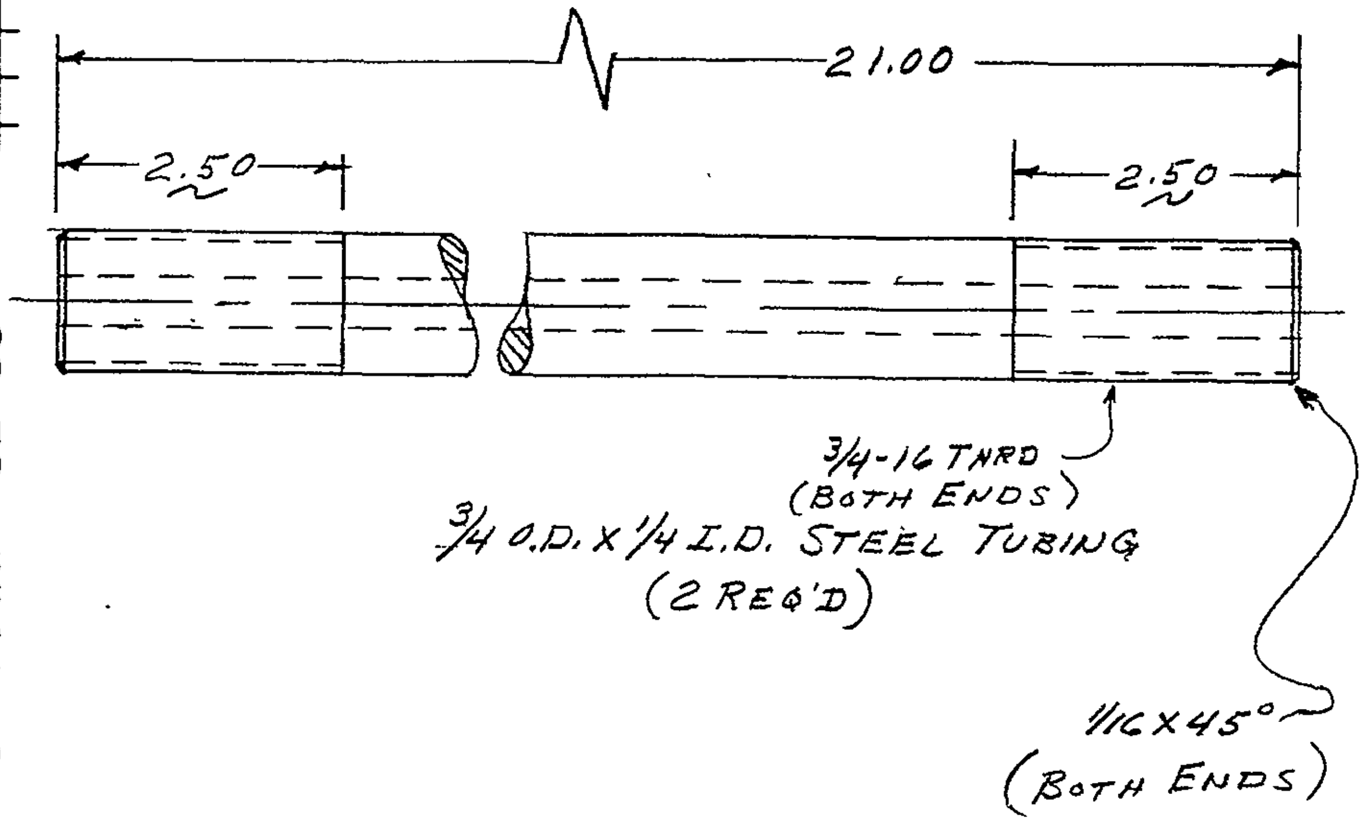

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SIDE RODS - CARRIAGE STROKE
JPL PROTOTYPE SAW

NOT OTHERWISE SPEC FRAC ± 1/64 ANG ± 1/4° | SCALE FULL

FIN. √ DEC X ± .1 XX ± .02 XXX ± .005

varian

DIVISION	SIZE	DRAWING NO	REV
VAC/LEX	A	S-1018	

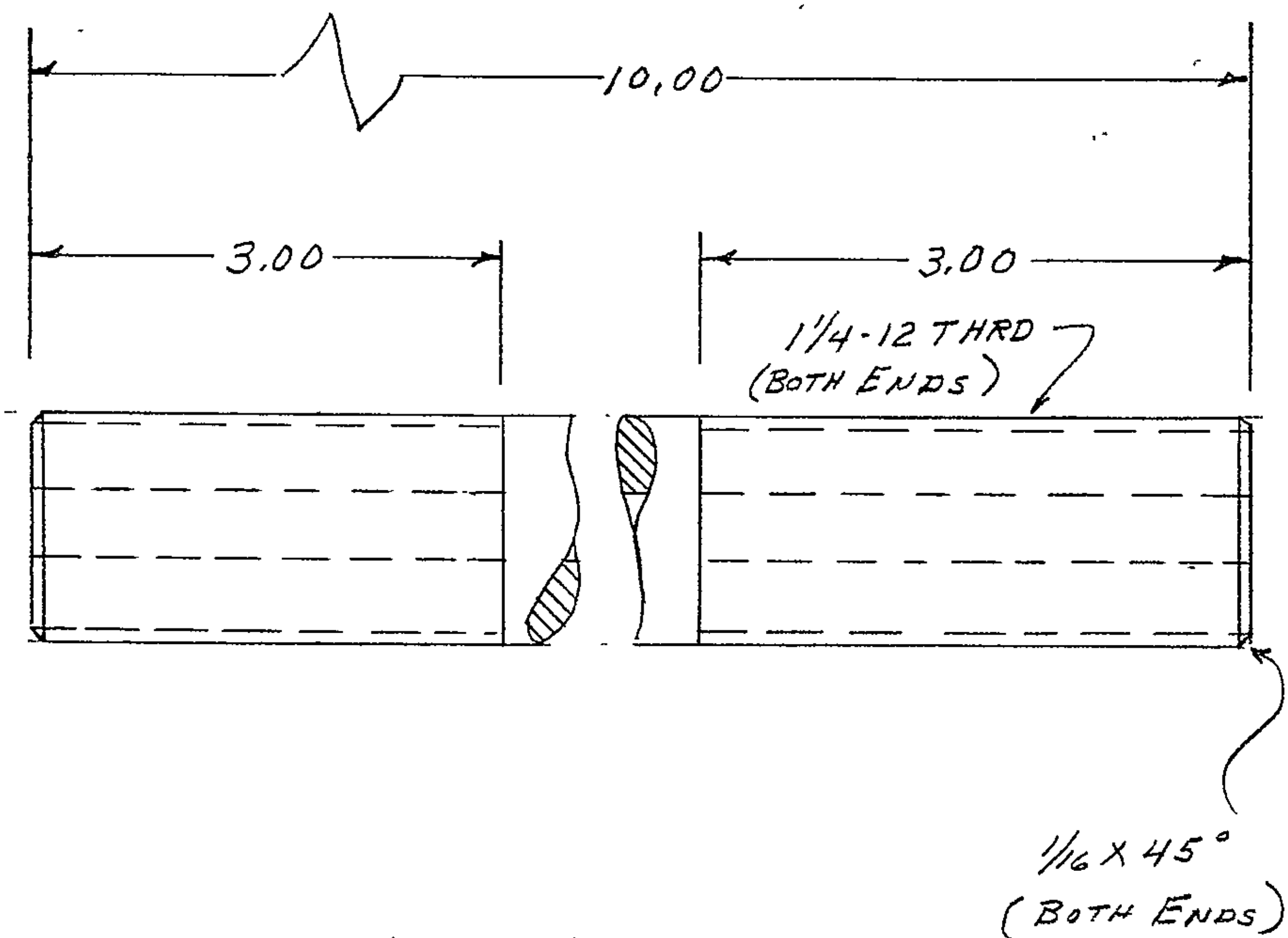
DESCRIPTION OF CHANGE

NUM	
EO	
DFT	
CHK	
DATE	
REV	

DASH NO	TYPE OR MODEL	NEXT ASSEMBLY	REQ	PART NUMBER	DESCRIPTION OR MATERIAL	ITEM

A S1019

DO NOT SCALE DRAWING



MAT'L - 1¼ O.D. X 3/8 I.D.
STEEL TUBING

ORIGINAL PAGE IS
OF POOR QUALITY

DO NOT SCALE THIS PRINT
UNLESS OTHERWISE SPECIFIED
BREAK ALL SHARP EDGES
DIMENSIONS ARE IN INCHES

DRAWN	DATE	APPROVED	DATE	CODE
GPB	10/25/77			✓
CHECKED	DATE	APPROVED	DATE	CLASS

MAIN DRIVE LINK
JPL PROTOTYPE SAW

NOT OTHERWISE SPEC FRAC ± 1/64 ANG ± 1/4°
FIN √ DEC X ± .1 XX ± .02 XXX ± .005

SCALE FULL

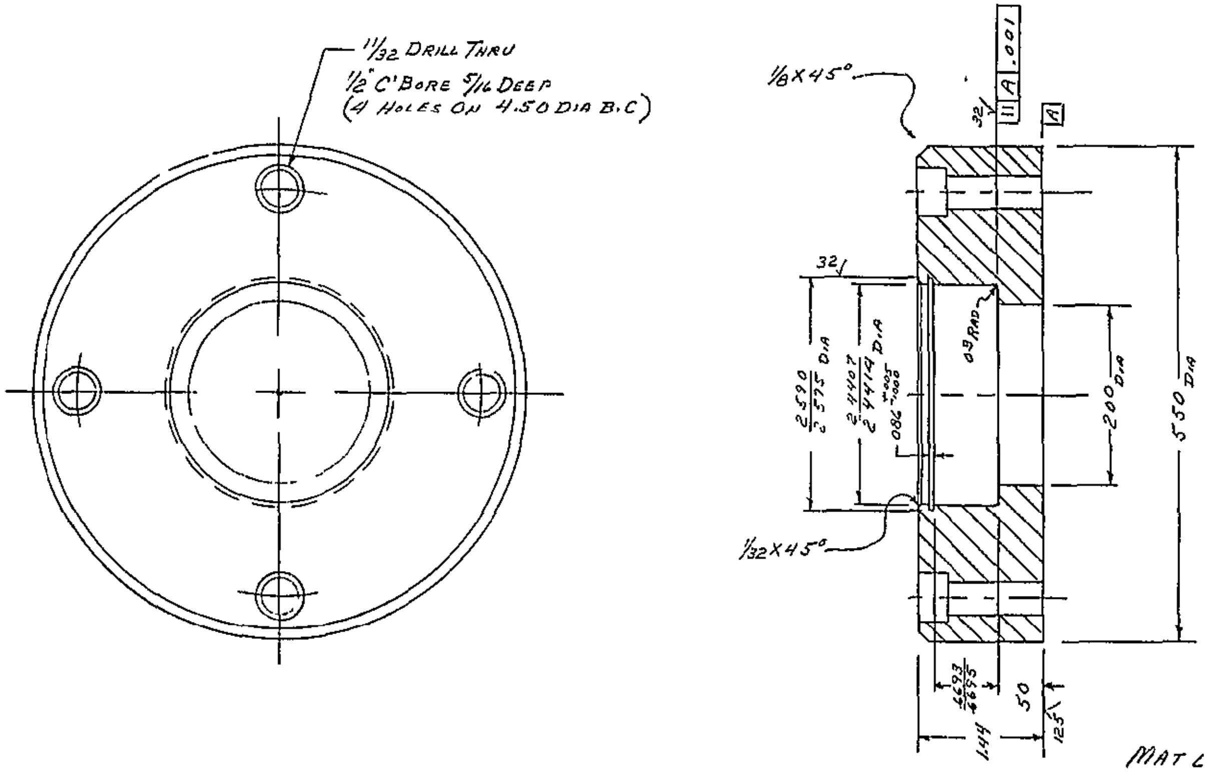
varian

DIVISION	SIZE	DRAWING NO	REV
VAC/LEX	A	S1019	

DESCRIPTION OF CHANGE	
NUM	
EO	
DFT	
CHK	
DATE	
REV	

REQ	PART NUMBER	DESCRIPTION OR MATERIAL	ITEM
		SNAP RING # N5000-244	
		BEARING - MRC 7305	

DASH NO.	TYPE OR MODEL	NEXT ASSEMBLY



MAT'L. - 5 1/2 DIA STEEL

DO NOT SCALE DRAWING

DRAWN	DATE	APPROVED	DATE	CODE
RPB	11/25/77			✓
CHECKED	DATE	APPROVED	DATE	CLASS

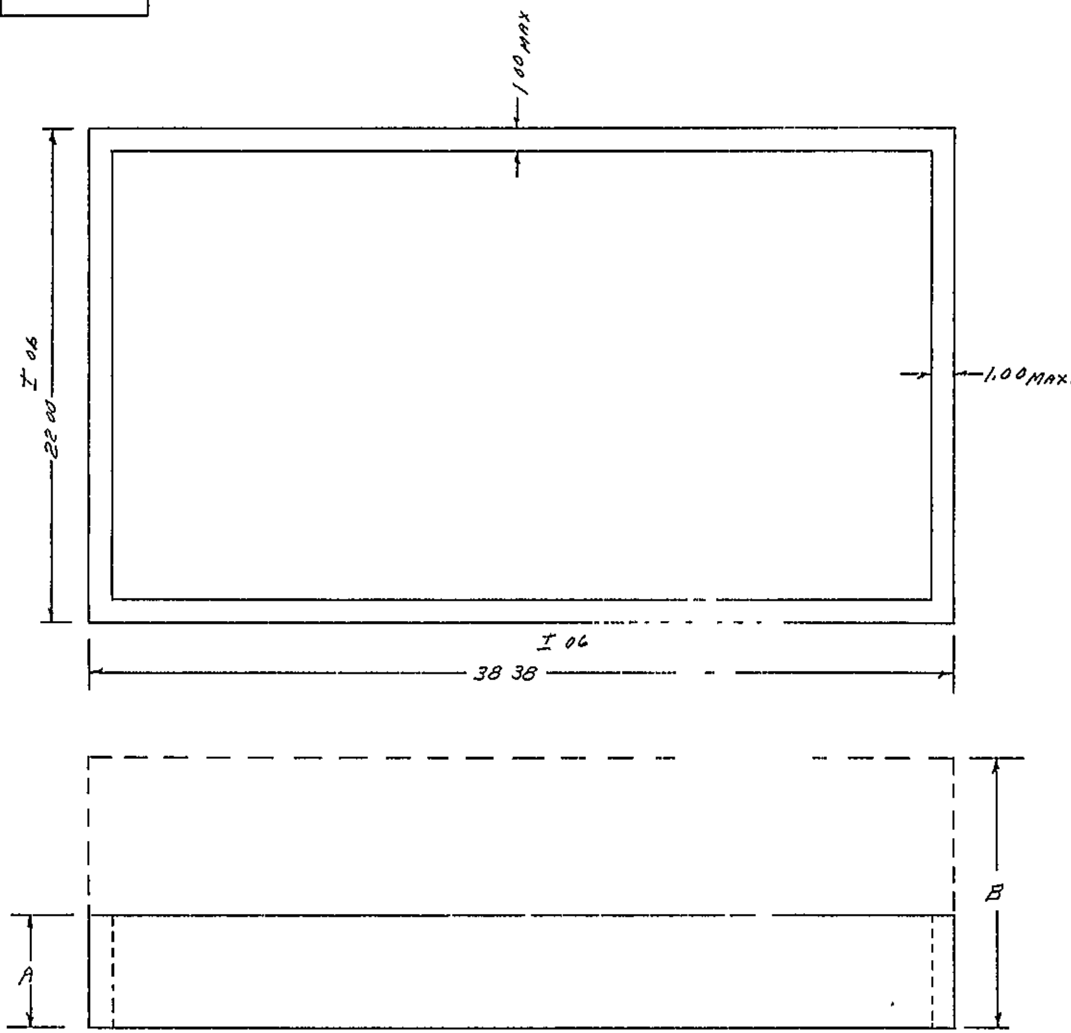
BEARING MOUNT - BALL SCREW
J.P.L PROTOTYPE SAW

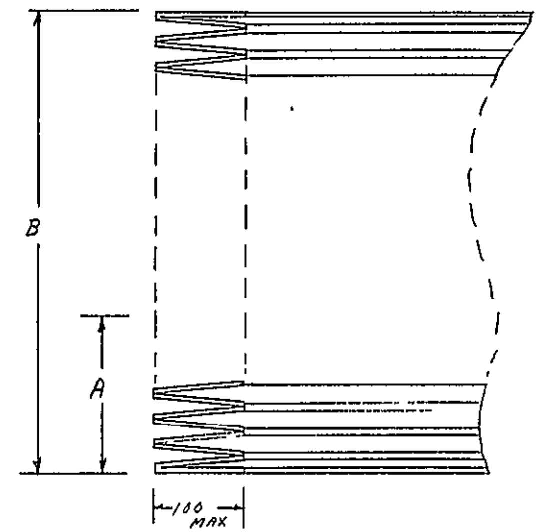
NOT OTHERWISE SPEC FRAC ± 1/64 ANG ± 1/4° FIN √ DEC X ± .1 XX ± .02 XXX ± .005 — SCALE FULL

varian — DIVISION: VAC/LEX — SIZE: C — DRAWING NO: S1020 — REV

DESCRIPTION OF CHANGE — NUM, ED, DFT, CHK, DATE, REV

441-6 5 APR66 LITHO IN U.S.A.





TYPICAL SECTION VIEW

A = 2½ MAX (COMPRESSED)

B = 12" MIN (EXTENDED)

DO NOT SCALE DRAWING

DRAWN RBB	DATE 10/26/77	APPROVED	DATE	CODE
CHECKED	DATE	APPROVED	DATE	CLASS

BELLOWS
JPL PROTOTYPE SAW

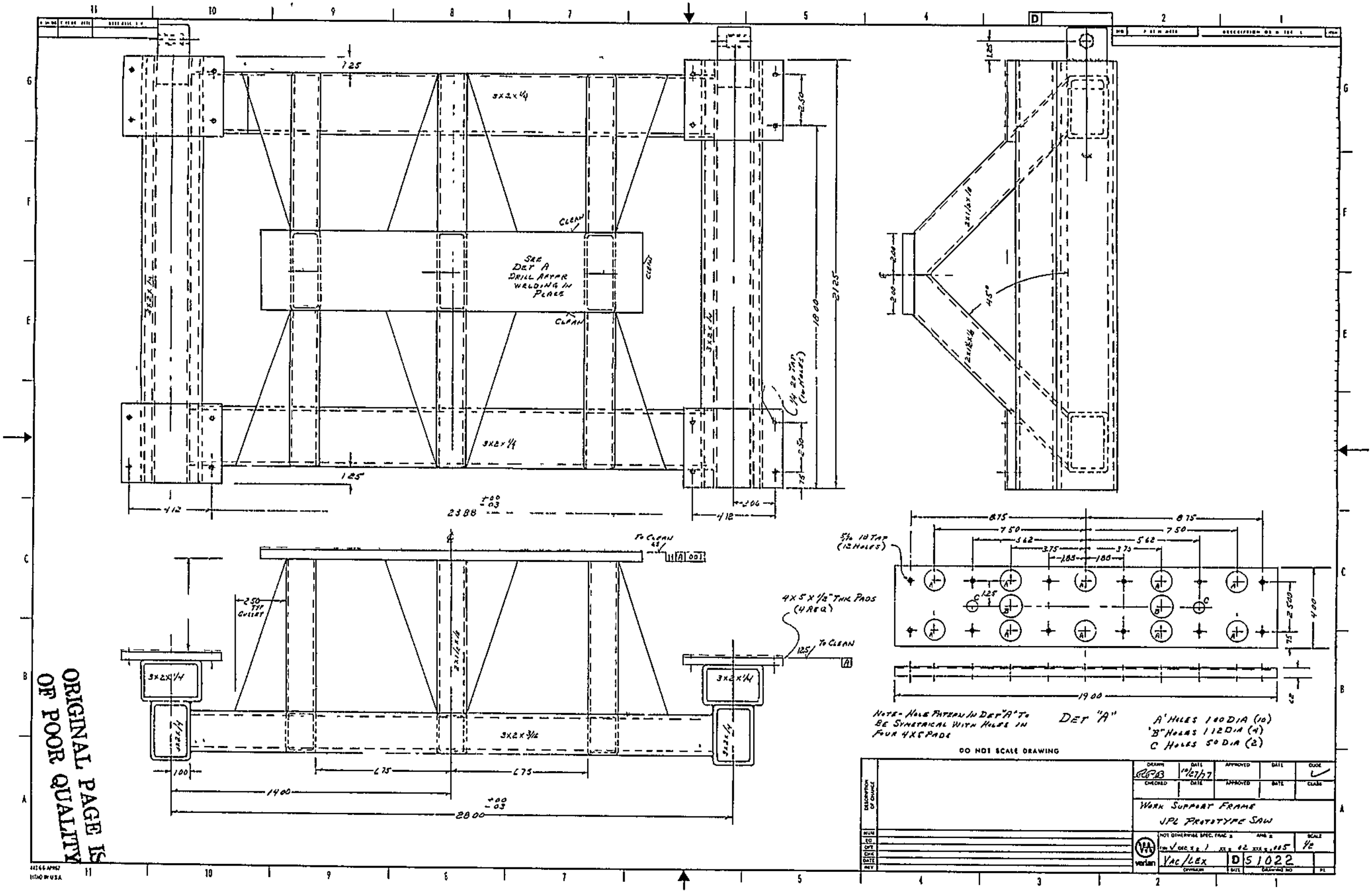
NOT OTHERWISE SPEC FRAC ±	ANG ±		SCALE
FIN ✓ DEC X ± .1	XX ± .02	XXX ± .005	1/4 = 1
DIVISION VAC/LEX	SIZE C	DRAWING NO S-1021	REV

varian

DESCRIPTION OF CHANGE — NUM / EO / DFT / CHK / DATE / REV

DASH NO | TYPE OR MODEL | NEXT ASSEMBLY

REQ | PART NUMBER | DESCRIPTION OR MATERIAL | ITEM



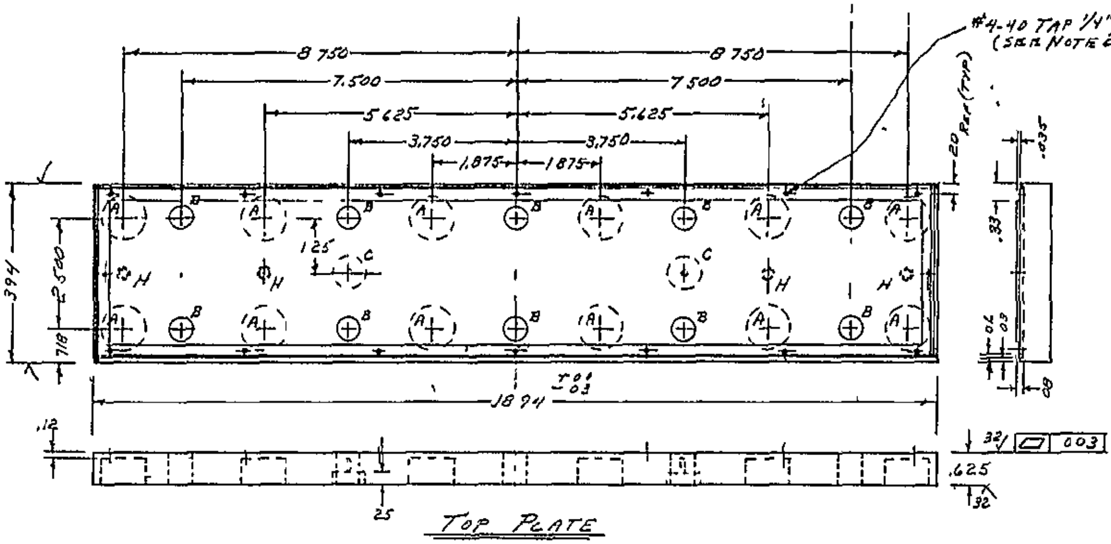
DO NOT SCALE DRAWING

WORK SUPPORT FRAME
JPL PROTOTYPE SAW

VAC/LEX

D 51022

Scale 1/2



TOP PLATE

DRILL LEGEND

A= 1.00 DIA TO DEPTH SHOWN

B= $\frac{.4990}{.4995}$ DIA THRU (SEE NOTE 1)

C= .75 DIA TO DEPTH SHOWN & 1-72 NF-28 TAP TO DEPTH SHOWN (DO NOT BREAK THRU)

D= 1.00 DIA TO DEPTH SHOWN & 11/32 DRILL THRU,

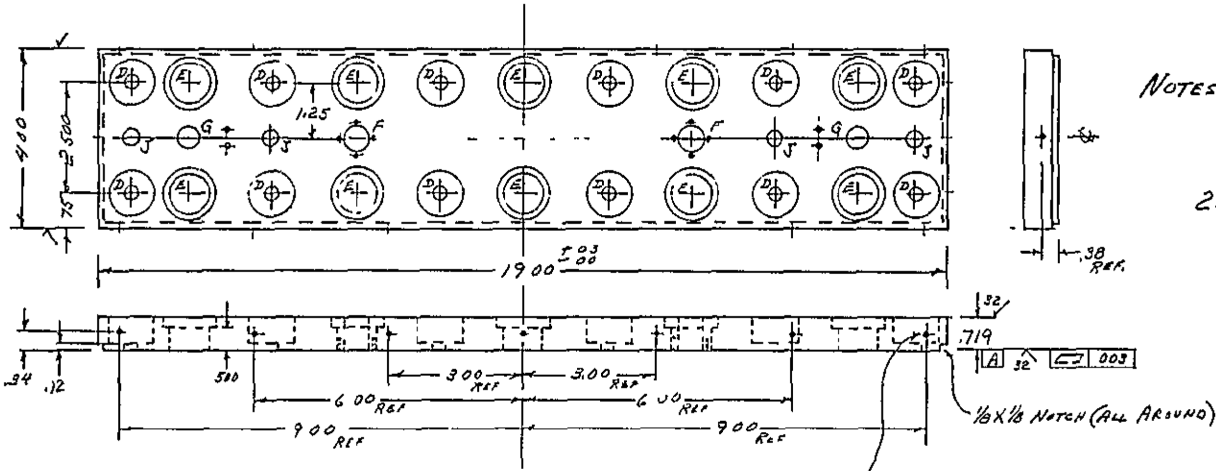
E= $\frac{.8740}{.8745}$ THRU & 1.121 DIA TO DEPTH SHOWN

F= $\frac{.501}{.503}$ DIA THRU & FOUR #2 56 TAPPED HOLES 1/4' DEEP (BOTTOM SIDE) ON .75 DIA B.C.

G= SEE DETAIL (AIR VENT)

H= 5/16-18 TAP 7/16 DEEP (FAR SIDE) (DO NOT BREAK THRU)

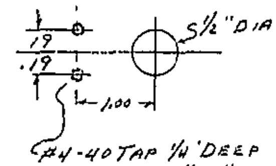
J= 13/32 DIA THRU (FOR SHOULDER SCREW)



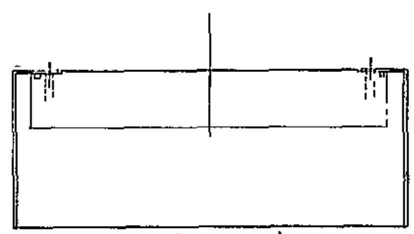
BOTTOM PLATE

NOTES - 1: HOLES "B" & HOLES 'E' TO BE BORED WITH PCS CLAMPED TOGETHER TO ASSURE PERFECT ALIGNMENT

2: HOLES MARKED REF TO BE DRILLED & TAPPED USING COVER AS TEMPLATE



DRILLING "G"



END VIEW (TOP PLATE)

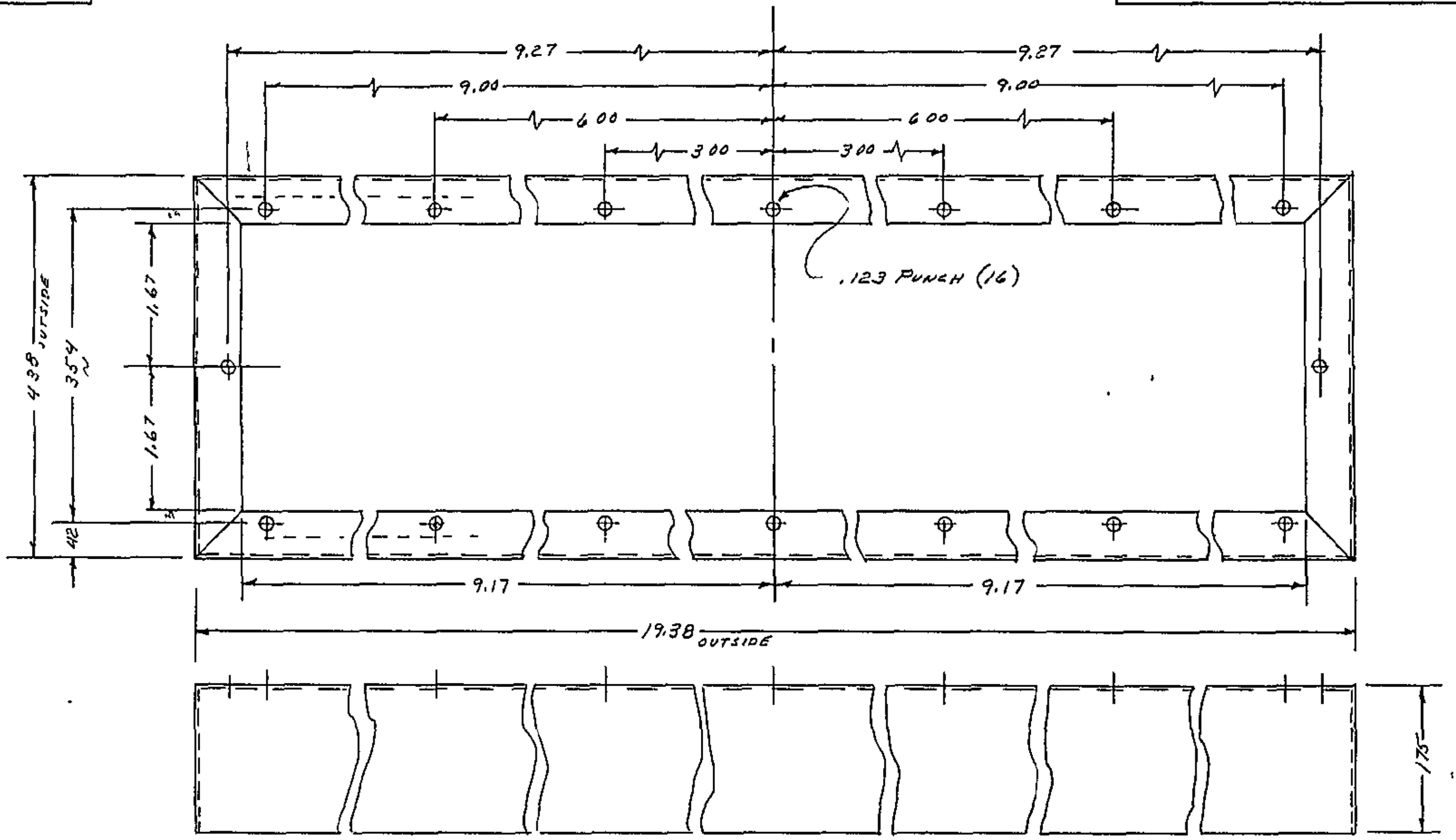
DO NOT SCALE DRAWING

DRAWN	RCB
DATE	10/27/77
TITLE	CUTTING PRESSURE PLATES JPL PROTOTYPE SAW
NOT OTHERWISE SPEC	FRAC ± 1/64 ANG ± 1/4° FIN √ DEC X ± .1 XX ± .02 XXX ± .005
SCALE	HALF
DIVISION	VAC/LEX
SIZE	C
DRAWING NO	S1023

varian

ORIGINAL PAGE IS OF POOR QUALITY

441-6-5 APR66 LITHO IN U.S.A.



MAT'L - .032 THK SHEET STEEL

DO NOT SCALE DRAWING

DRAWN	DATE	APPROVED	DATE	CODE
GBG3				
CHECKED	DATE	APPROVED	DATE	CLASS

UPPER SLURRY SHIELD
JPL PROTOTYPE SAW

NOT OTHERWISE SPEC FRAC ± ANG ± SCALE FULL
FIN √ DEC X ±.1 XX ± .02 XXX ± .005

varian

DIVISION	SIZE	DRAWING NO	REV
VAC/LEX	C	S1024	

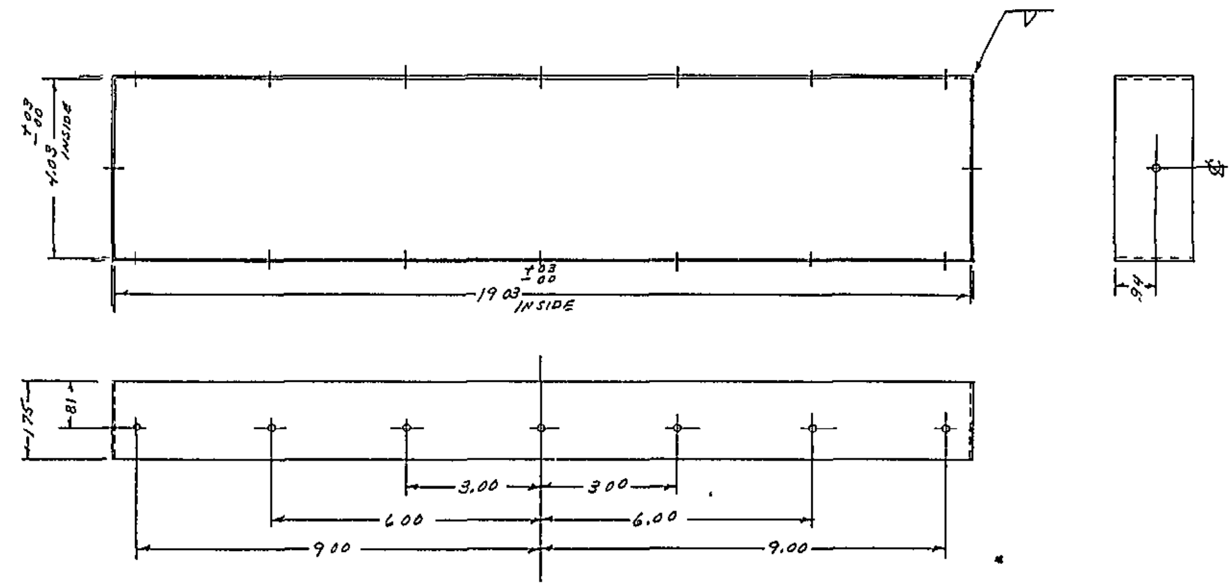
DESCRIPTION OF CHANGE

NUM / EO / DFT / CHK / DATE / REV

DASH NO. | TYPE OR MODEL | NEXT ASSEMBLY

REQ | PART NUMBER | DESCRIPTION OR MATERIAL | ITEM

441-6-5 APR66 LITHO IN U.S.A.



MAT'L - .032 THK SHEET STEEL

DO NOT SCALE DRAWING

ORIGINAL PAGE IS OF POOR QUALITY

DRAWN	DATE	APPROVED	DATE	CODE
RBB	10/20/77			
CHECKED	DATE	APPROVED	DATE	CLASS

LOWER SLURRY SHIELD
JPL PROTOTYPE SAW

NOT OTHERWISE SPEC FRAC ± ANG ± FIN √ DEC X ± .1 XX ± .02 XXX ± .005

SCALE: HALF

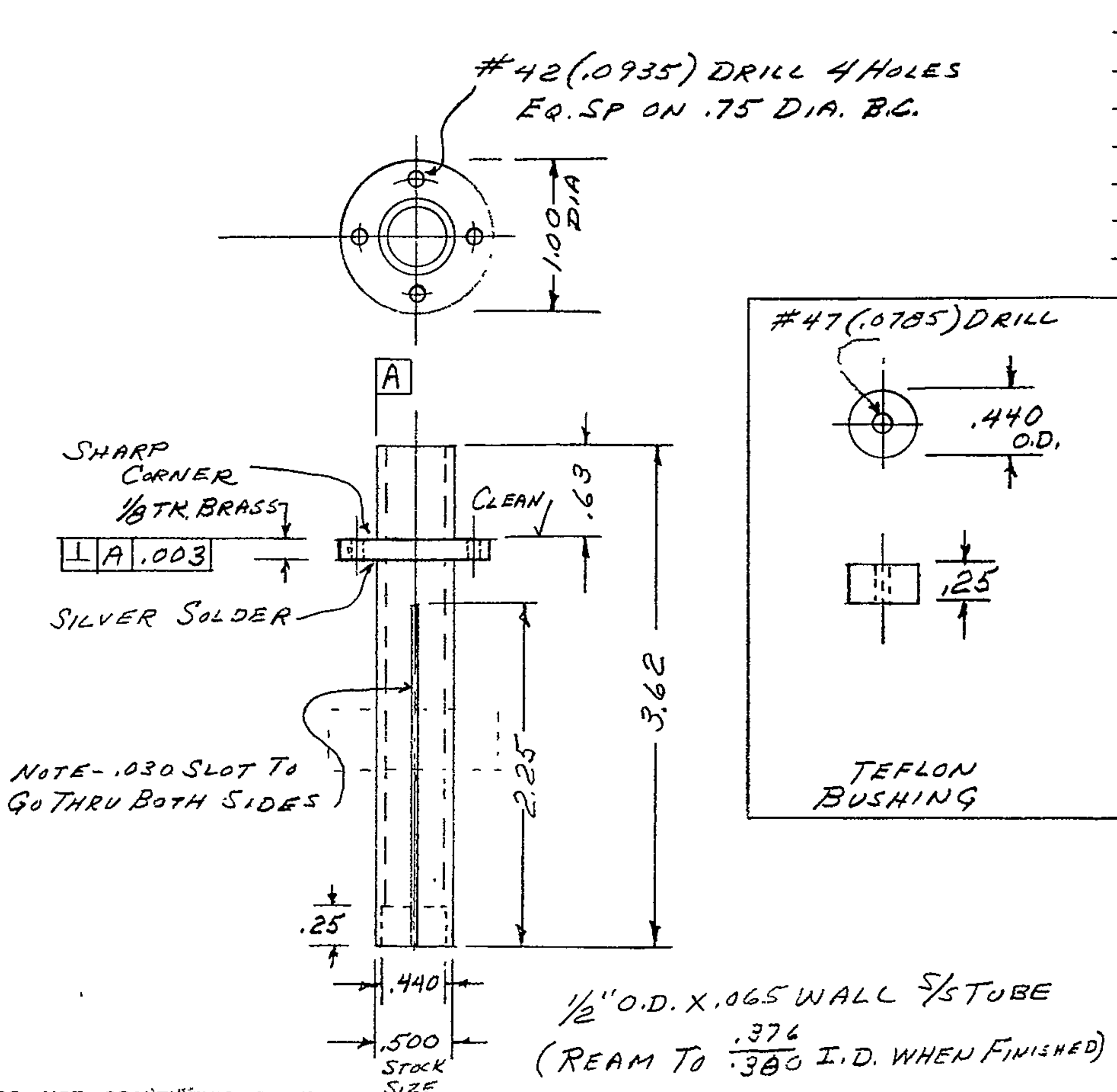
varian | VAC/LEX | SIZE: C | DRAWING NO: 51025 | REV

DESCRIPTION OF CHANGE; NUM; EO; DFT; CHK; DATE; REV

441-6-5 APR66 LITHO IN U.S.A.

A S1026

DASH NO	TYPE OR MODEL	NEXT ASSEMBLY	REQ	PART NUMBER	DESCRIPTION OR MATERIAL	ITEM
			1		CLAMP TITE COLLAR #15414 S/S	1



DO NOT SCALE DRAWING

DO NOT SCALE THIS PRINT
UNLESS OTHERWISE SPECIFIED
BREAK ALL SHARP EDGES
DIMENSIONS ARE IN INCHES

DRAWN	DATE	APPROVED	DATE	CODE
RPB				✓
CHECKED	DATE	APPROVED	DATE	CLASS

LVDT MOUNTING TUBE
JPL PROTOTYPE SAW

NOT OTHERWISE SPEC	FRAC ±	ANG ±	SCALE
FIN ✓ DEC X ±.1	XX ±.02	XXX ±.005	FULL

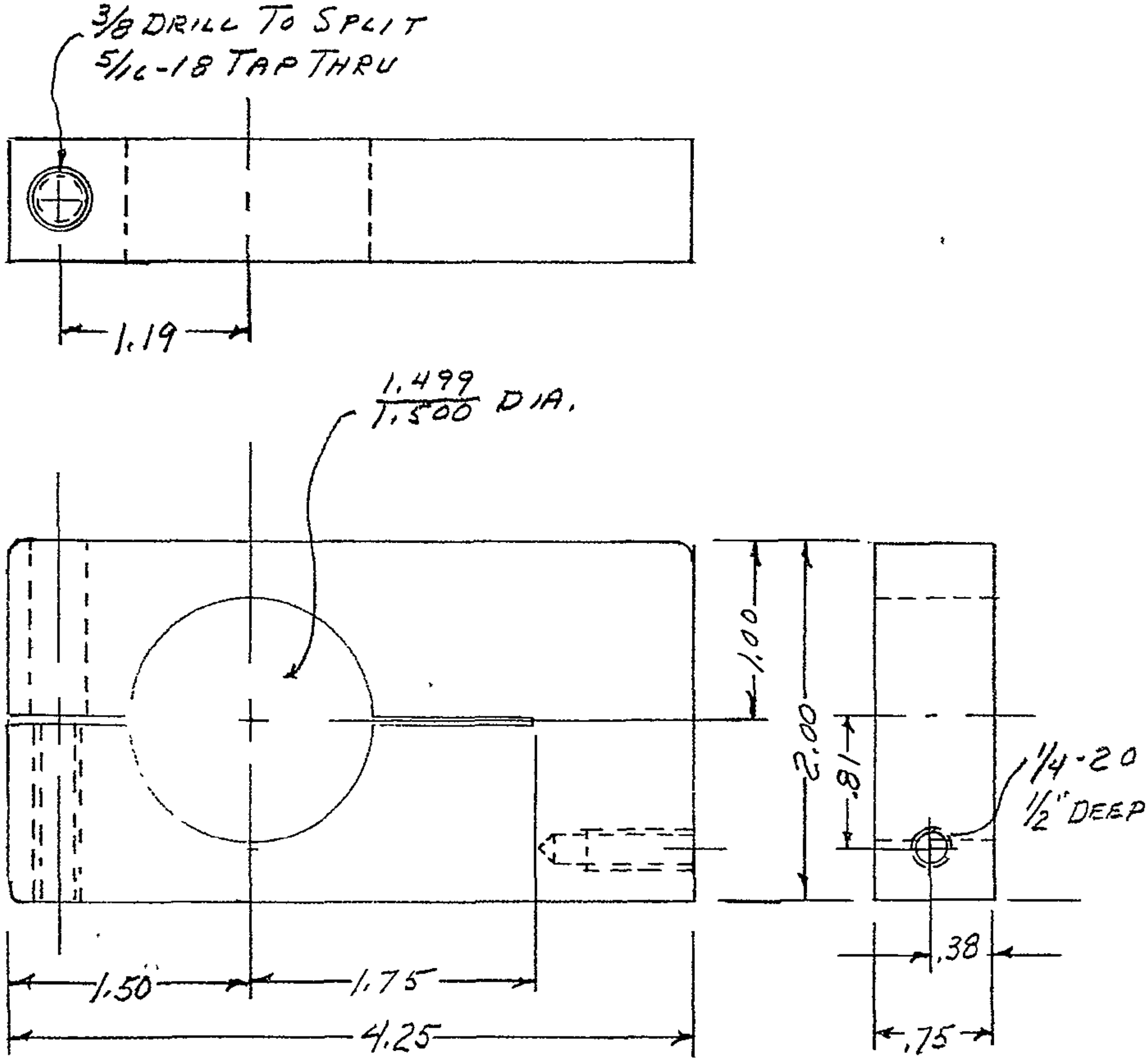
DIVISION	SIZE	DRAWING NO	REV
VAC/LEX	A	S 1026	

varian

DESCRIPTION OF CHANGE
NUM
EO
DFT
CHK
DATE
REV

DASH NO	TYPE OR MODEL	NEXT ASSEMBLY	REQ	PART NUMBER	DESCRIPTION OR MATERIAL	ITEM

A | S-1027



DO NOT SCALE DRAWING

DO NOT SCALE THIS PRINT
UNLESS OTHERWISE SPECIFIED
BREAK ALL SHARP EDGES
DIMENSIONS ARE IN INCHES

DRAWN	DATE	APPROVED	DATE	CODE
RRG3	10/28/77			
CHECKED	DATE	APPROVED	DATE	CLASS

SLURRY SHIELD SUPPORT
JPL PROTOTYPE SAW

NOT OTHERWISE SPEC FRAC ± ANG ± | SCALE FULL

FIN √ DEC X ±.1 XX ±.02 XXX ±.005

varian

DIVISION	SIZE	DRAWING NO	REV
VAC/LEX	A	S 1027	

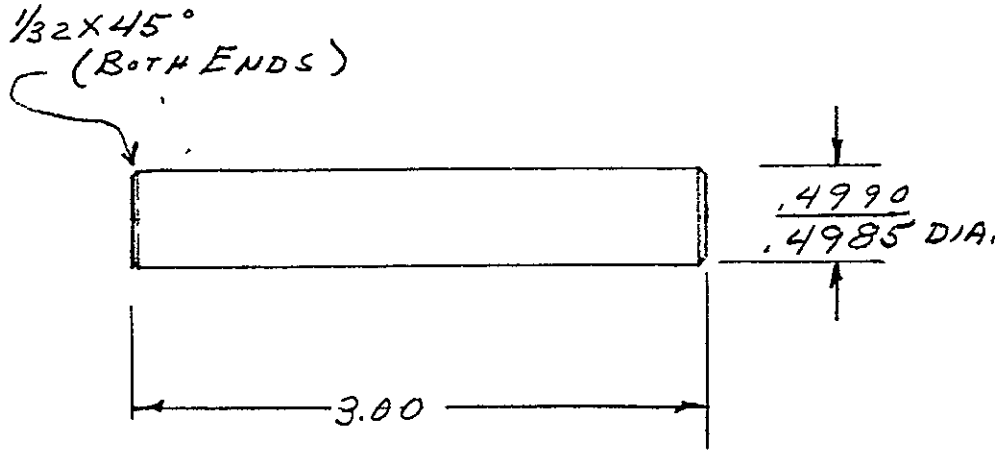
DESCRIPTION OF CHANGE

NUM	
EO	
DFT	
CHK	
DATE	
REV	

DASH NO	TYPE OR MODEL	NEXT ASSEMBLY	REQ	PART NUMBER	DESCRIPTION OR MATERIAL	ITEM

A 51028

DO NOT SCALE DRAWING



SOLID 60 CASE HARDENED & GROUND CLASS S" SHAFTING

ORIGINAL PAGE IS OF POOR QUALITY

10 PCS REQ'D.

DO NOT SCALE THIS PRINT
UNLESS OTHERWISE SPECIFIED
BREAK ALL SHARP EDGES
DIMENSIONS ARE IN INCHES

DRAWN	DATE	APPROVED	DATE	CODE
RPB	10/31/77			✓
CHECKED	DATE	APPROVED	DATE	CLASS

GUIDE PINS
JPL PROTOTYPE SAW

NOT OTHERWISE SPEC FRAC ± ANG ± FIN ✓ DEC X ± XX ± XXX ±

SCALE FULL

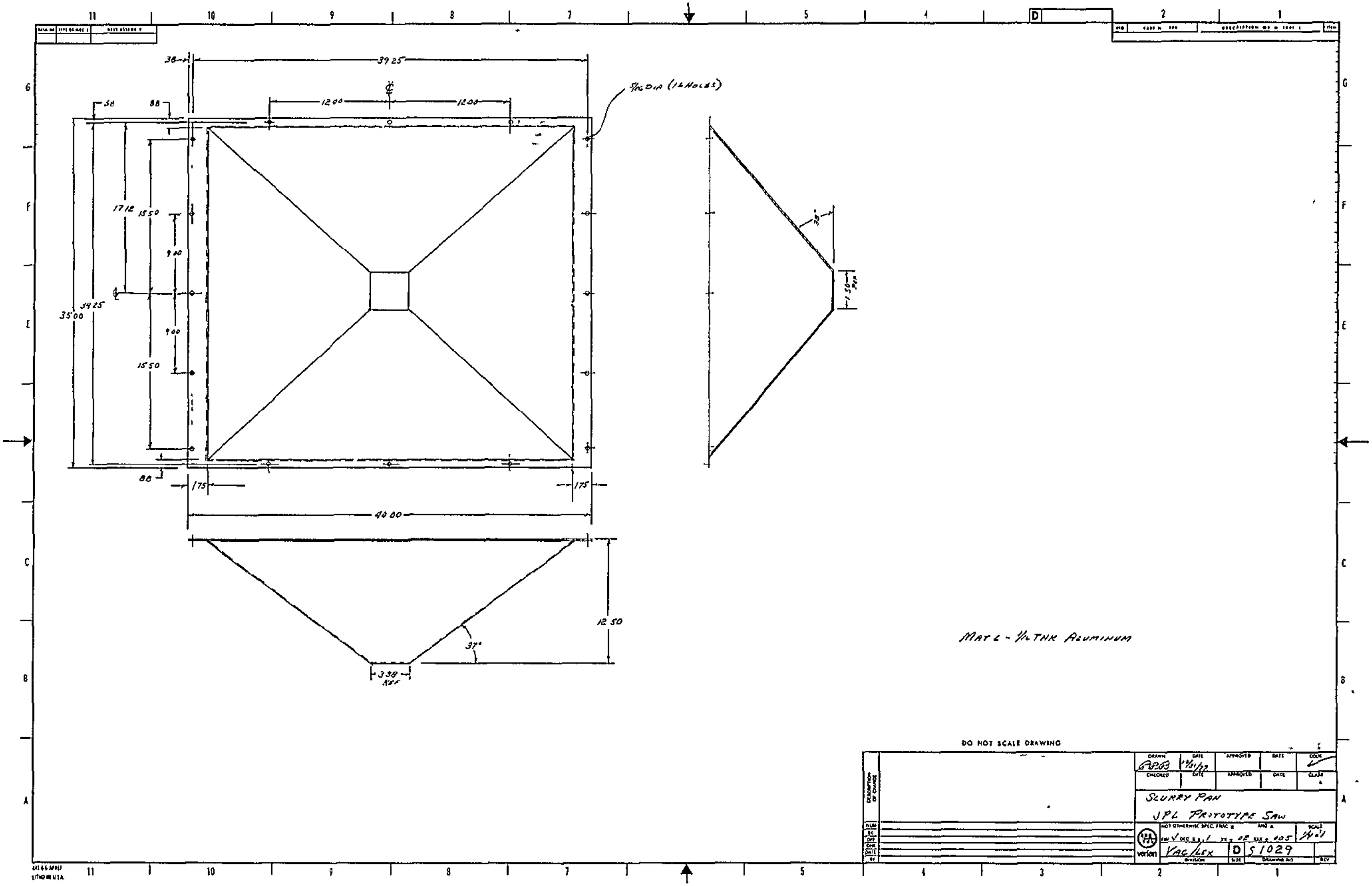
varian

DIVISION	SIZE	DRAWING NO.	REV
VAC/LEX	A	51028	

DESCRIPTION OF CHANGE

NUM	
EO	
DFT	
CHK	
DATE	
REV	

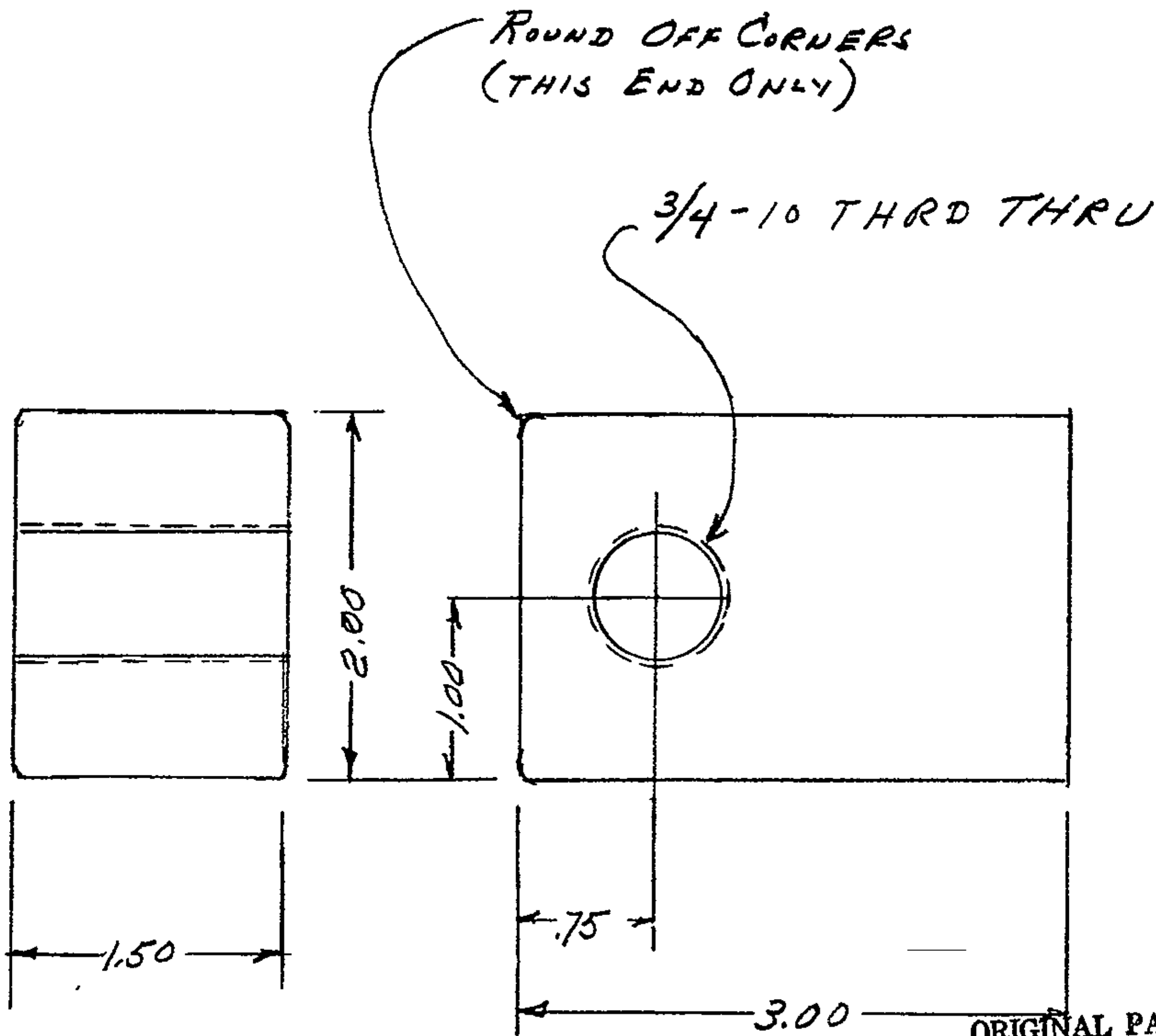
LITHO IN U.S.A.



38
39.25
12.00
12.00
℄
5/16 DIA (12 HOLES)
.38
.88
17.12
15.50
9.00
9.00
15.50
34.25
35.00
.88
.175
.175
40.00
12.50
37°
3.38 REF
1.50
MAT'L - 1/16 THK ALUMINUM
DO NOT SCALE DRAWING
DRAWN GPB
DATE 10/31/77
SLURRY PAN
JPL PROTOTYPE SAW
SCALE 1/4=1
VAC/LEX
D
51029
varian

DASH NO	TYPE OR MODEL	NEXT ASSEMBLY	REQ	PART NUMBER	DESCRIPTION OR MATERIAL	ITEM

A S/032



ORIGINAL PAGE IS OF POOR QUALITY

MAT'L - 1½ X 2 M/S

DO NOT SCALE DRAWING

DO NOT SCALE THIS PRINT
UNLESS OTHERWISE SPECIFIED
BREAK ALL SHARP EDGES
DIMENSIONS ARE IN INCHES

DRAWN	DATE	APPROVED	DATE	CODE
RPB	11/15/77			✓
CHECKED	DATE	APPROVED	DATE	CLASS

DESCRIPTION OF CHANGE

NUM	
EO	
DFT	
CHK	
DATE	
REV	

PIVOT BLOCKS
JPL PROTOTYPE

NOT OTHERWISE SPEC FRAC ± ANG ± SCALE FULL

FIN ✓ DEC X ± XX ± XXX ±

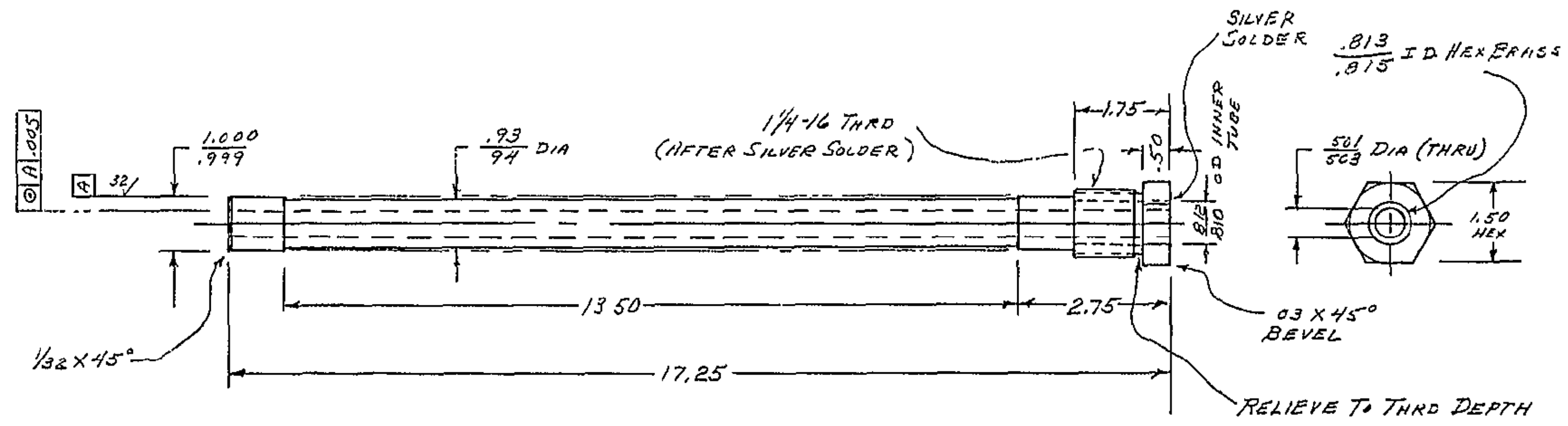
varian

DIVISION	SIZE	DRAWING NO	REV
VAC/LEX	A	S 1032	

DASH NO	TYPE OR MODEL	NEXT ASSEMBLY

REQ	PART NUMBER	DESCRIPTION OR MATERIAL	ITEM

DO NOT SCALE DRAWING



MAT'L - 1" OD X 1/4" WALL HARD BRASS TUBE & 1 1/2 HEX BRASS

DO NOT SCALE THIS PRINT
UNLESS OTHERWISE SPECIFIED
BREAK ALL SHARP EDGES
DIMENSIONS ARE IN INCHES

DESCRIPTION OF CHANGE

NUM / EO / DFT / CHK / DATE / REV

DRAWN	DATE	APPROVED	DATE	CODE
RBG	10/18/77			✓
CHECKED	DATE	APPROVED	DATE	CLASS

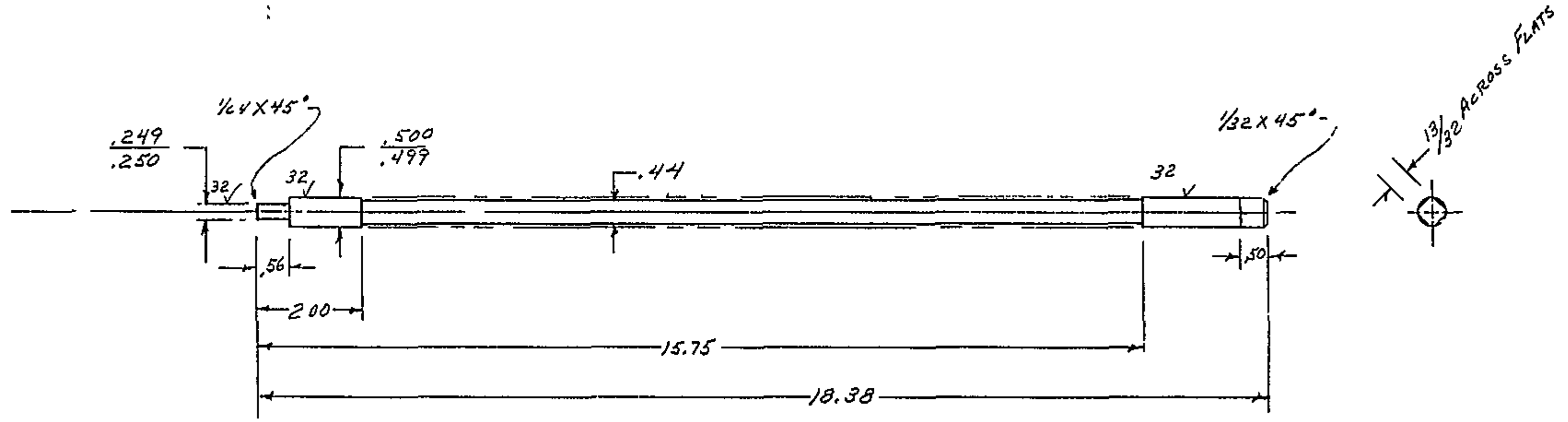
LOCKING SHAFT STRIKE ADJ
JPL PROTOTYPE SAW

NOT OTHERWISE SPEC FRAC ± 1/64 ANG ± 1/4°
FIN √ DEC X ± .1 XX ± .02 XXX ± .005
SCALE 1/2

varian

DIVISION	SIZE	DRAWING NO	REV
VAC/LEX	B	C-1033	

44164 JUNE66 LITHO IN U.S.A.



1/2" DIA. DRILL ROD

DASH NO	TYPE OR MODEL	NEXT ASSEMBLY

REQ	PART NUMBER	DESCRIPTION OR MATERIAL	ITEM

DO NOT SCALE DRAWING

ORIGINAL PAGE IS OF POOR QUALITY

DO NOT SCALE THIS PRINT
UNLESS OTHERWISE SPECIFIED
BREAK ALL SHARP EDGES
DIMENSIONS ARE IN INCHES

DESCRIPTION OF CHANGE

NUM / EO / DFT / CHK / DATE / REV

DRAWN	DATE	APPROVED	DATE	CODE
R.P. Bell	10/18/77			✓
CHECKED	DATE	APPROVED	DATE	CLASS

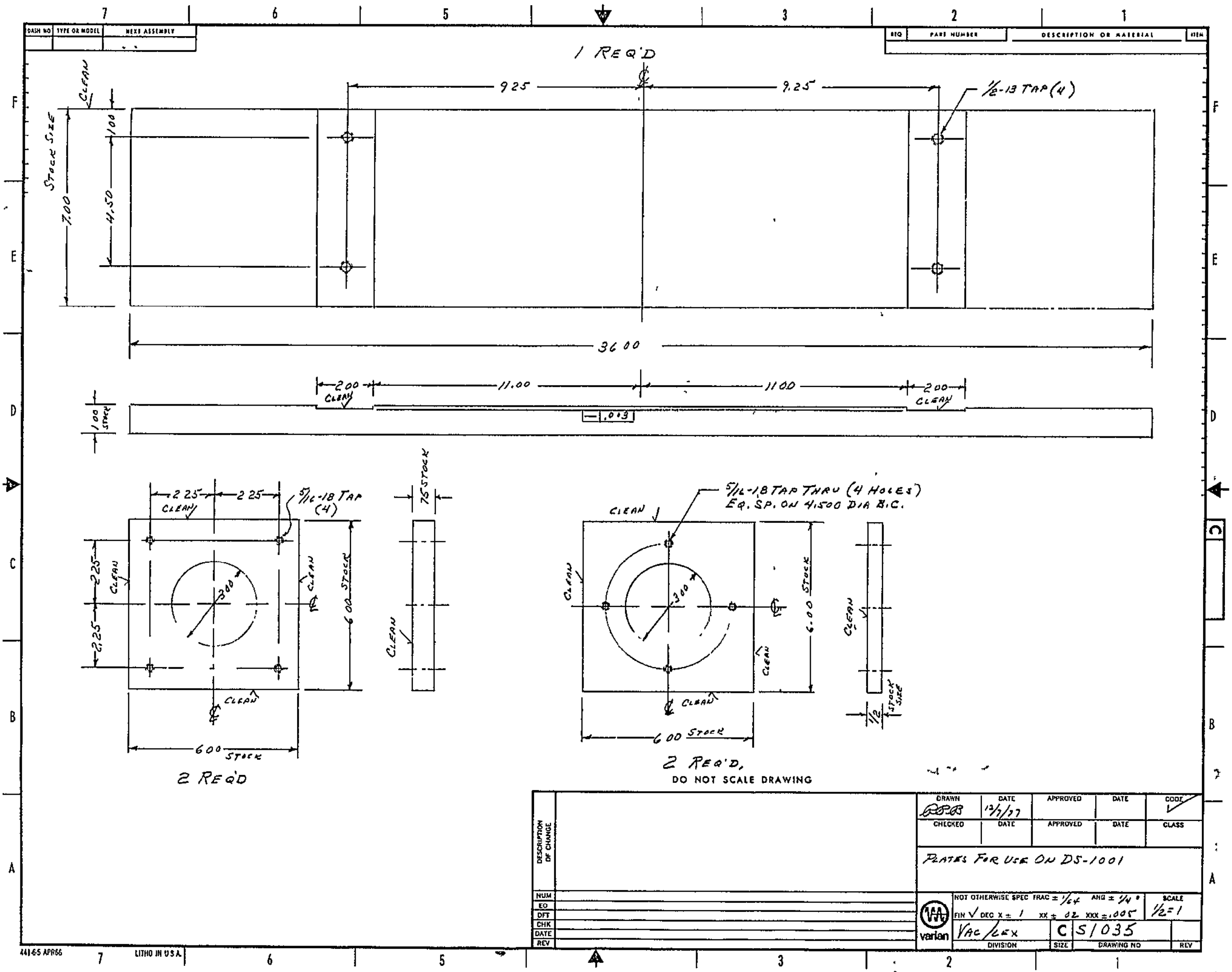
ADJUSTING SCREW-STROKE ADJ
JPL PROTOTYPE SAW

NOT OTHERWISE SPEC FRAC ± 1/64 ANG ± 1° | SCALE 1/2
FIN ✓ DEC X ± .1 XX ± .02 XXX ± .005

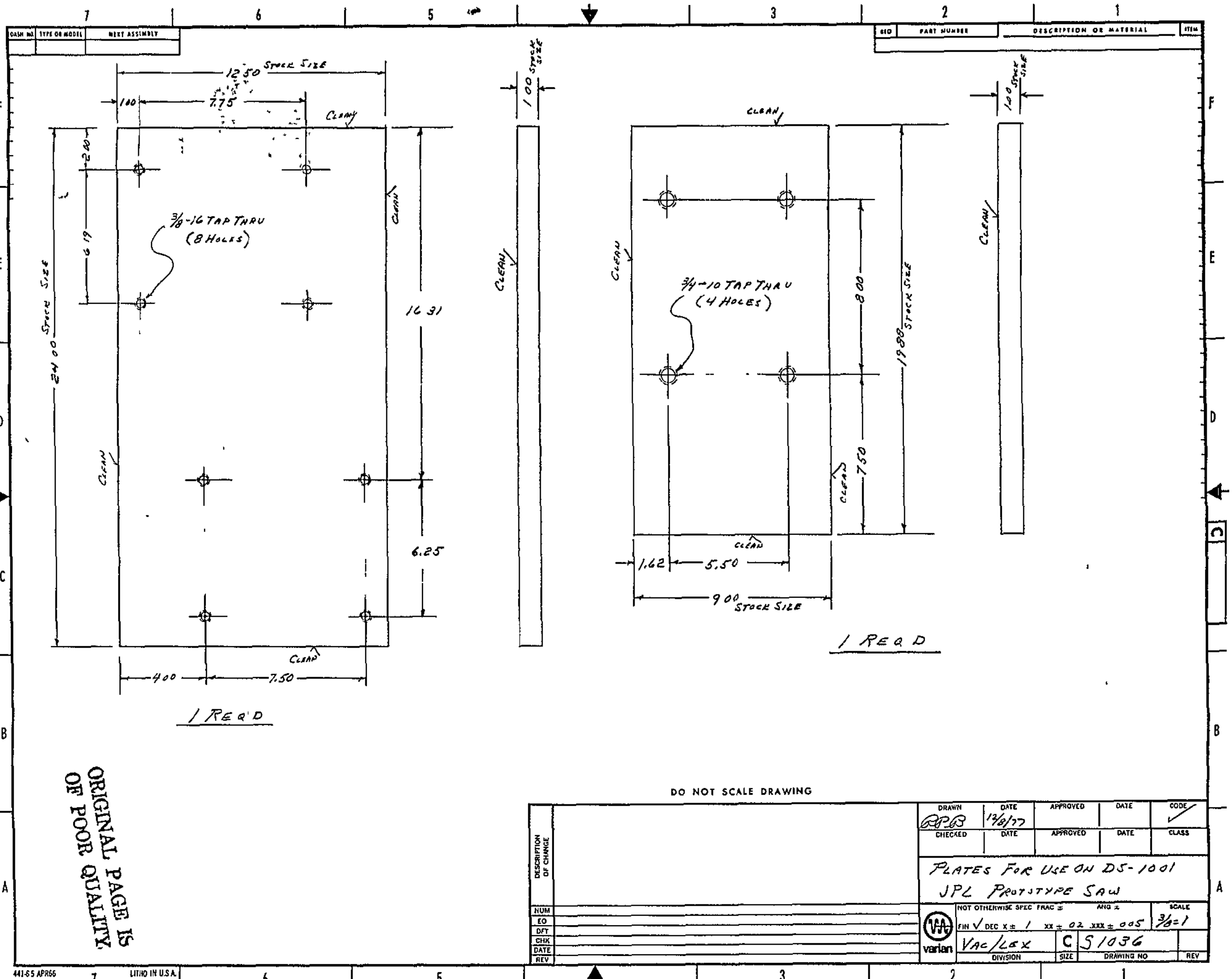
varian

DIVISION	SIZE	DRAWING NO	REV
VAC/LEX	B	5-1034	

44164 JUNE66 LITHO IN U S A



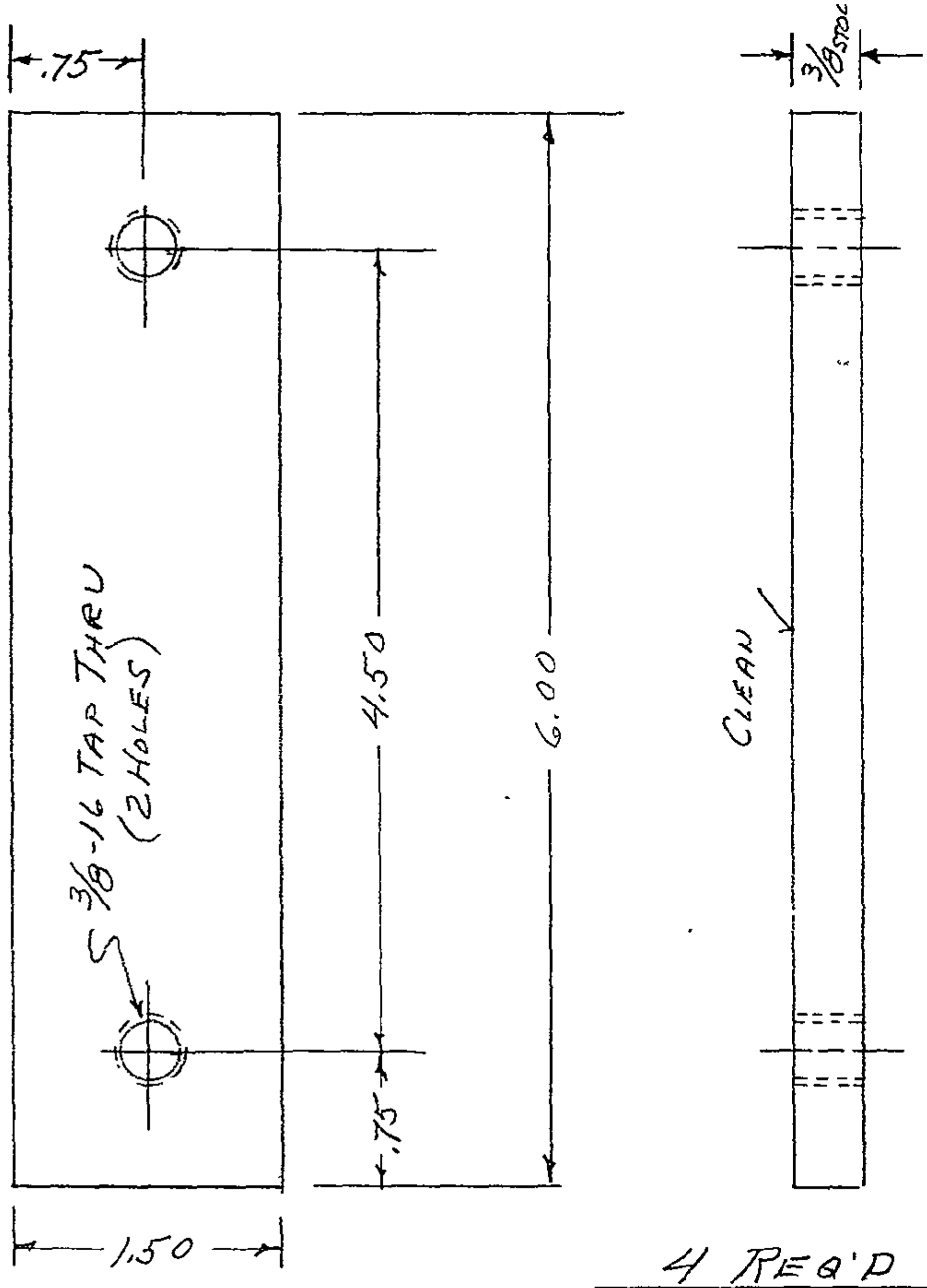
DASH NO
TYPE OR MODEL
NEXT ASSEMBLY
REQ
PART NUMBER
DESCRIPTION OR MATERIAL
ITEM
1 REQ'D
9.25
9.25
1/2-13 TAP (4)
CLEAN
STOCK SIZE
7.00
1.00
4.50
36.00
2.00
11.00
11.00
2.00
CLEAN
CLEAN
1.00 STOCK
.003
2.25
2.25
5/16-18 TAP (4)
CLEAN
.75 STOCK
2.25
2.25
CLEAN
CLEAN
3.00
6.00 STOCK
CLEAN
CLEAN
6.00 STOCK
2 REQ'D
5/16-18 TAP THRU (4 HOLES)
EQ. SP. ON 4.500 DIA B.C.
CLEAN
CLEAN
3.00
6.00 STOCK
CLEAN
CLEAN
CLEAN
1/2 STOCK SIZE
6.00 STOCK
2 REQ'D,
DO NOT SCALE DRAWING
DESCRIPTION OF CHANGE
NUM
EO
DFT
CHK
DATE
REV
DRAWN
DATE
12/7/77
APPROVED
DATE
CODE
CHECKED
DATE
APPROVED
DATE
CLASS
PLATES FOR USE ON DS-1001
NOT OTHERWISE SPEC FRAC ± 1/64 ANG ± 1/4°
FIN √ DEC X ± .1 XX ± .02 XXX ± .005
SCALE
1/2=1
varian
VAC /LEX
DIVISION
C
SIZE
S1035
DRAWING NO
REV
441-65 APR66
LITHO IN U.S.A.



DASH NO. | TYPE OR MODEL | NEXT ASSEMBLY
FIND | PART NUMBER | DESCRIPTION OR MATERIAL | ITEM
12.50 STOCK SIZE
1.00
7.75
CLEAN
2.00
6.19
3/8-16 TAP THRU (8 HOLES)
24.00 STOCK SIZE
16.31
6.25
4.00
7.50
1 REQ'D
1.00 STOCK SIZE
3/4-10 TAP THRU (4 HOLES)
8.00
7.50
19.88 STOCK SIZE
1.62
5.50
9.00 STOCK SIZE
1 REQ'D
DO NOT SCALE DRAWING
DESCRIPTION OF CHANGE
NUM
EO
DFT
CHK
DATE
REV
DRAWN RPB
DATE 12/8/77
APPROVED
DATE
CODE
CHECKED
CLASS
PLATES FOR USE ON DS-1001
JPL PROTOTYPE SAW
NOT OTHERWISE SPEC FRAC ± ANG ±
FIN √ DEC X ± .1 XX ± .02 XXX ± .005
SCALE 3/8=1
varian
VAC/LEX
DIVISION
C
SIZE
S1036
DRAWING NO
441-65 APR66
LITHO IN U.S.A.

DASH NO	TYPE OR MODEL	NEXT ASSEMBLY	REQ	PART NUMBER	DESCRIPTION OR MATERIAL	ITEM
		DS-1001				

A S-1037



4 REQ'D

DO NOT SCALE DRAWING

DO NOT SCALE THIS PRINT
UNLESS OTHERWISE SPECIFIED
BREAK ALL SHARP EDGES
DIMENSIONS ARE IN INCHES

DRAWN	DATE	APPROVED	DATE	CODE
RPB	12/12/77			
CHECKED	DATE	APPROVED	DATE	CLASS

SHAFT SUPPORT MOUNTING PADS

NOT OTHERWISE SPEC FRAC ± 1/64 ANG ± 1/4°
FIN ✓ DEC X ± .1 XX ± .02 XXX ± .005

SCALE FULL

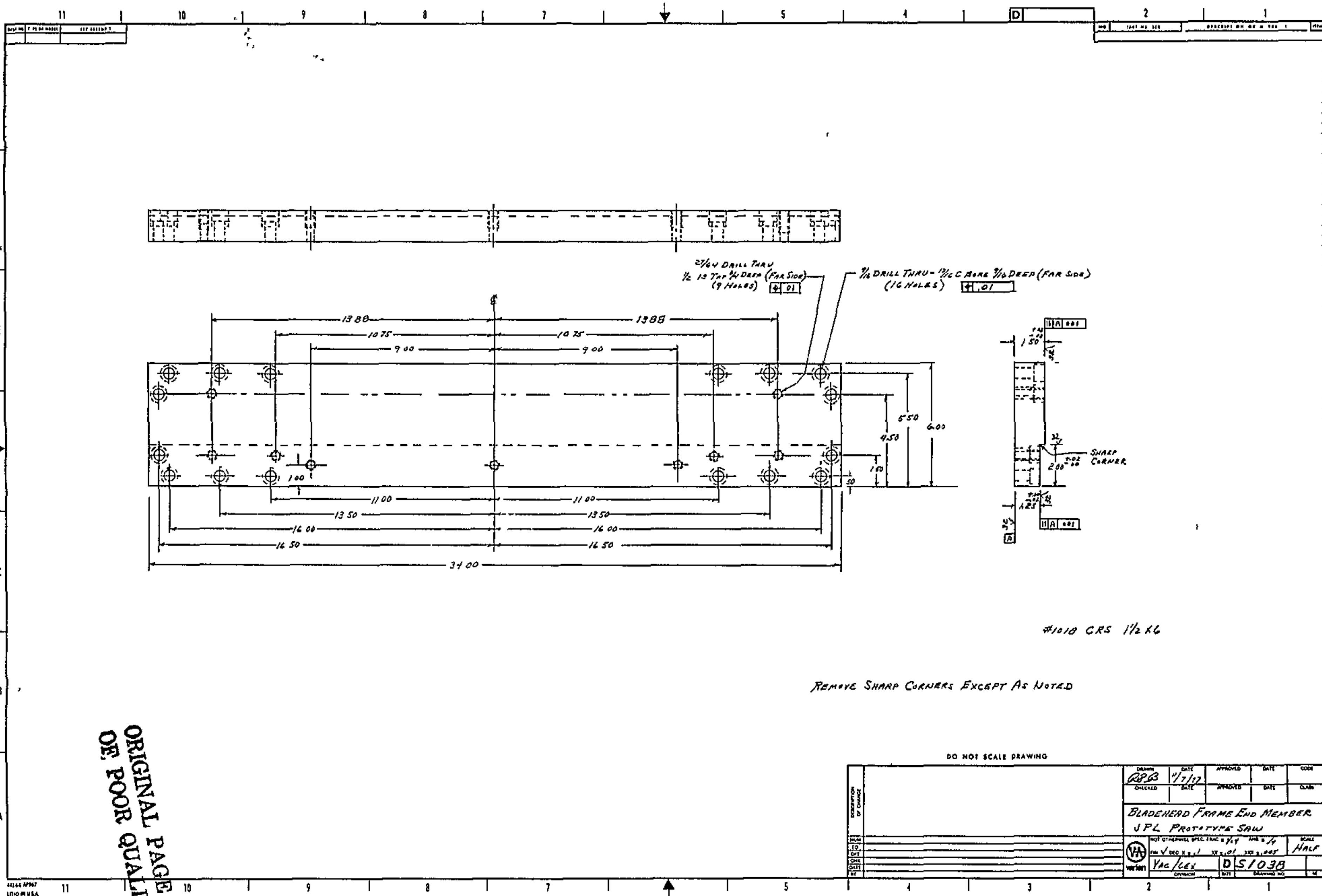
varian

DIVISION	SIZE	DRAWING NO	REV
VAC/LEX	A	S-1037	

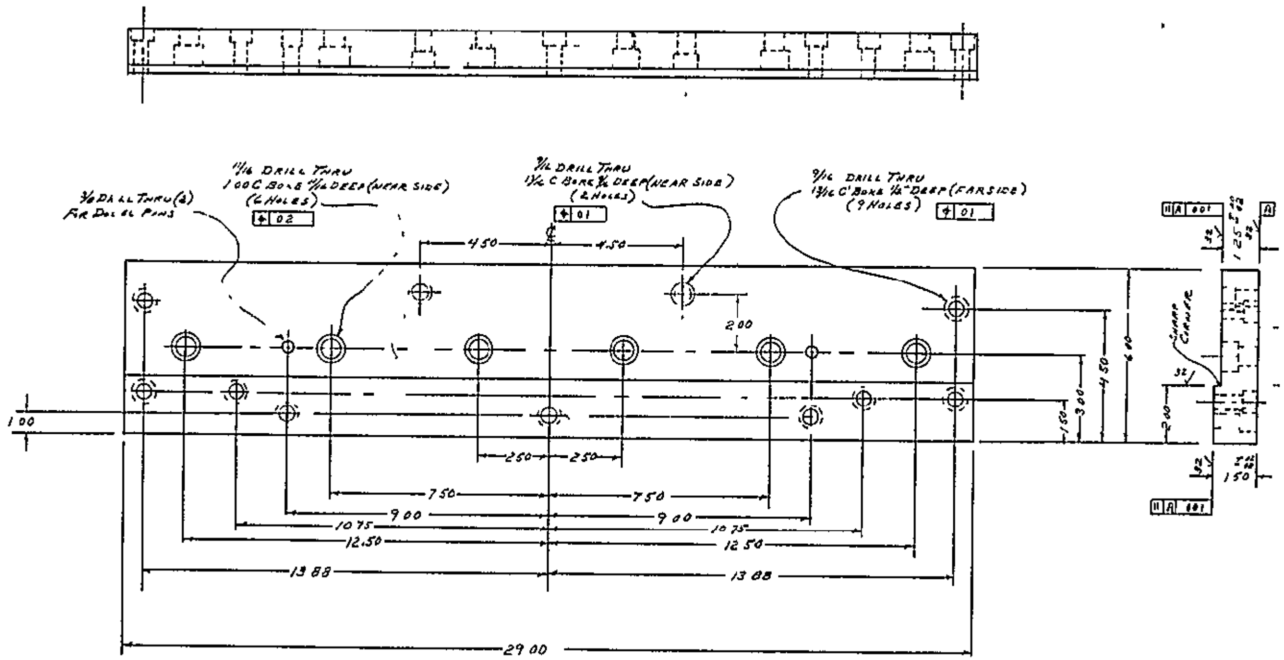
DESCRIPTION OF CHANGE

NUM	
EO	
DFT	
CHK	
DATE	
REV	

LITHO IN U.S.A.
411-6-3 MAY



27/64 DRILL THRU
1/2 13 TAP 3/4 DEEP (FAR SIDE)
(9 HOLES)
.01
9/16 DRILL THRU - 13/16 C BORE 9/16 DEEP (FAR SIDE)
(16 HOLES)
.01
13 88
13 88
10 75
10 75
9 00
9 00
5 50
4 50
6 00
1 50
1 00
.50
11 00
11 00
13 50
13 50
16 00
16 00
16 50
16 50
34 00
1 50
2 00
SHARP CORNER
A .001
A .001
#1018 CRS 1 1/2 X 6
REMOVE SHARP CORNERS EXCEPT AS NOTED
DO NOT SCALE DRAWING
DRAWN
DATE
11/7/77
APPROVED
DATE
CODE
CHECKED
DATE
APPROVED
DATE
CLASS
DESCRIPTION OF CHANGE
BLADEHEAD FRAME END MEMBER
JPL PROTOTYPE SAW
SCALE
HALF
varian
VAC / LEX
DIVISION
D
S1038
DRAWING NO



32 ALL OVER

#1018 CRS 1 3/4 X 6

NOTE- REMOVE SHARP CORNERS EXCEPT WHERE NOTED

DO NOT SCALE DRAWING

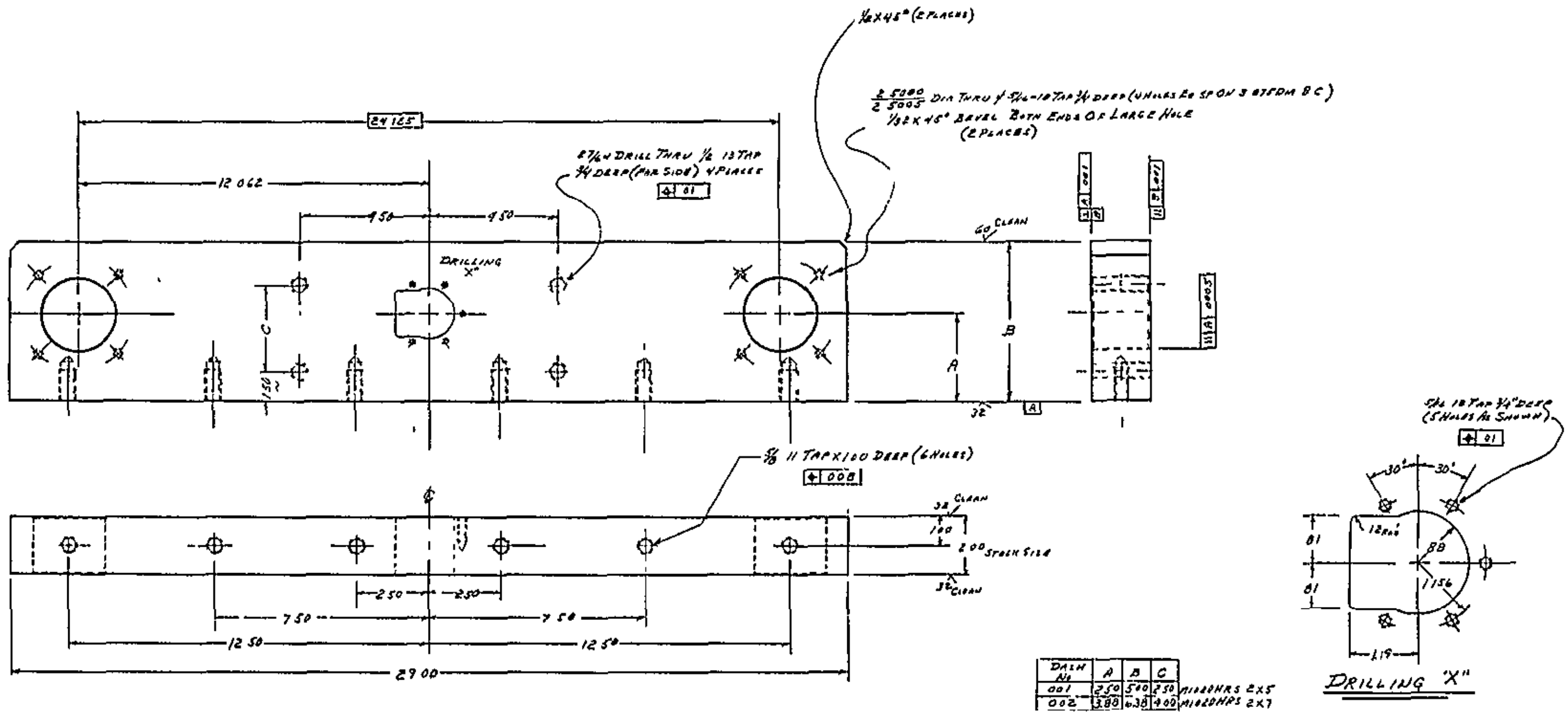
DRAWN	DATE	APPROVED	DATE	CODE
RPB	11/12/77			
CHECKED	DATE	APPROVED	DATE	CLASS

VERTICAL BLADEHEAD SUPPORTS (L & R)
JPL PROTOTYPE SAW

SCALE: HALF

VAC/LEX — D 51039

varian

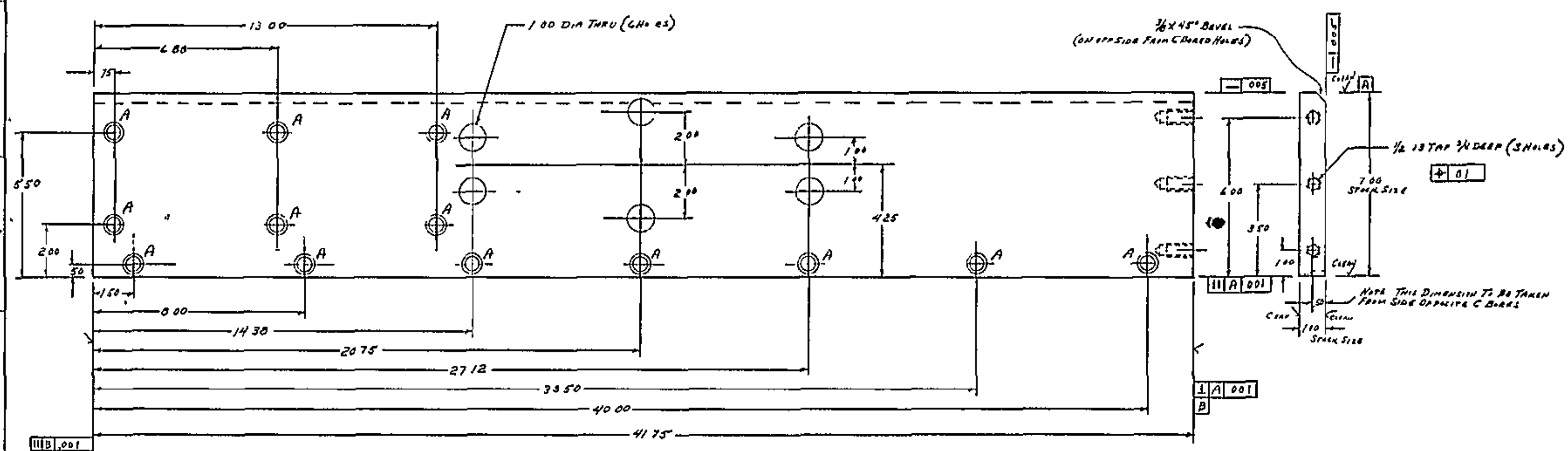


DASH No	A	B	C	
001	2.50	5.00	2.50	M1020HRS 2X5
002	3.88	6.38	4.00	M1020HRS 2X7

END SUPPORTS - BLA" "EAD
JPL PROTOTYPE SAW

DRAWN: 11/10/77
SCALE: HALF
VAC / LEY
D 31049
varian

DASH No	A	⌖ 01
001	9/16 DRILL THRU - 11/16 C BORE 1/2" DEEP (NEAR SIDE)	
002	9/16 DRILL THRU - 11/16 C BORE 1/2" DEEP (FAR SIDE)	



$^{32}\sqrt{}$ ALL OVER

#1018 CRS 1X7

DO NOT SCALE DRAWING

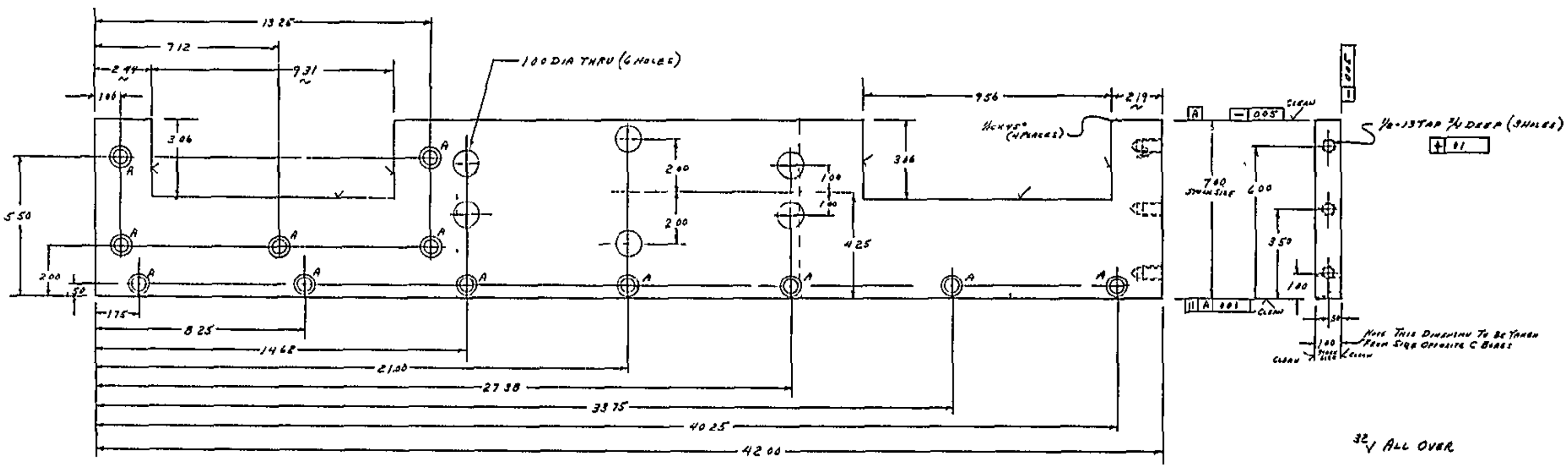
DRAWN	DATE	APPROVED	DATE	CLASS
RPB	11/28/77			
CHECKED	DATE	APPROVED	DATE	CLASS

BOTTOM SIDE PLATES (BLADEHEAD)
JPL PROTOTYPE SAW

NOT OTHERWISE SPEC. FRAC ± 1/64 ANG ± 1/4° FIN √ DEC X ± .1 XX ± .01 XXX ± .005 SCALE 1/2 = 1

varian VAC / LAR D S1041

DASH NO	A ⌖ .01
001	9/16 DRILL THRU - 15/16 C'BORE 1/2" DEEP (NEAR SIDE)
002	9/16 DRILL THRU 15/16 C'BORE 1/2" DEEP (FAR SIDE)



32√ ALL OVER

#1018 CRS 1X7

DO NOT SCALE DRAWING

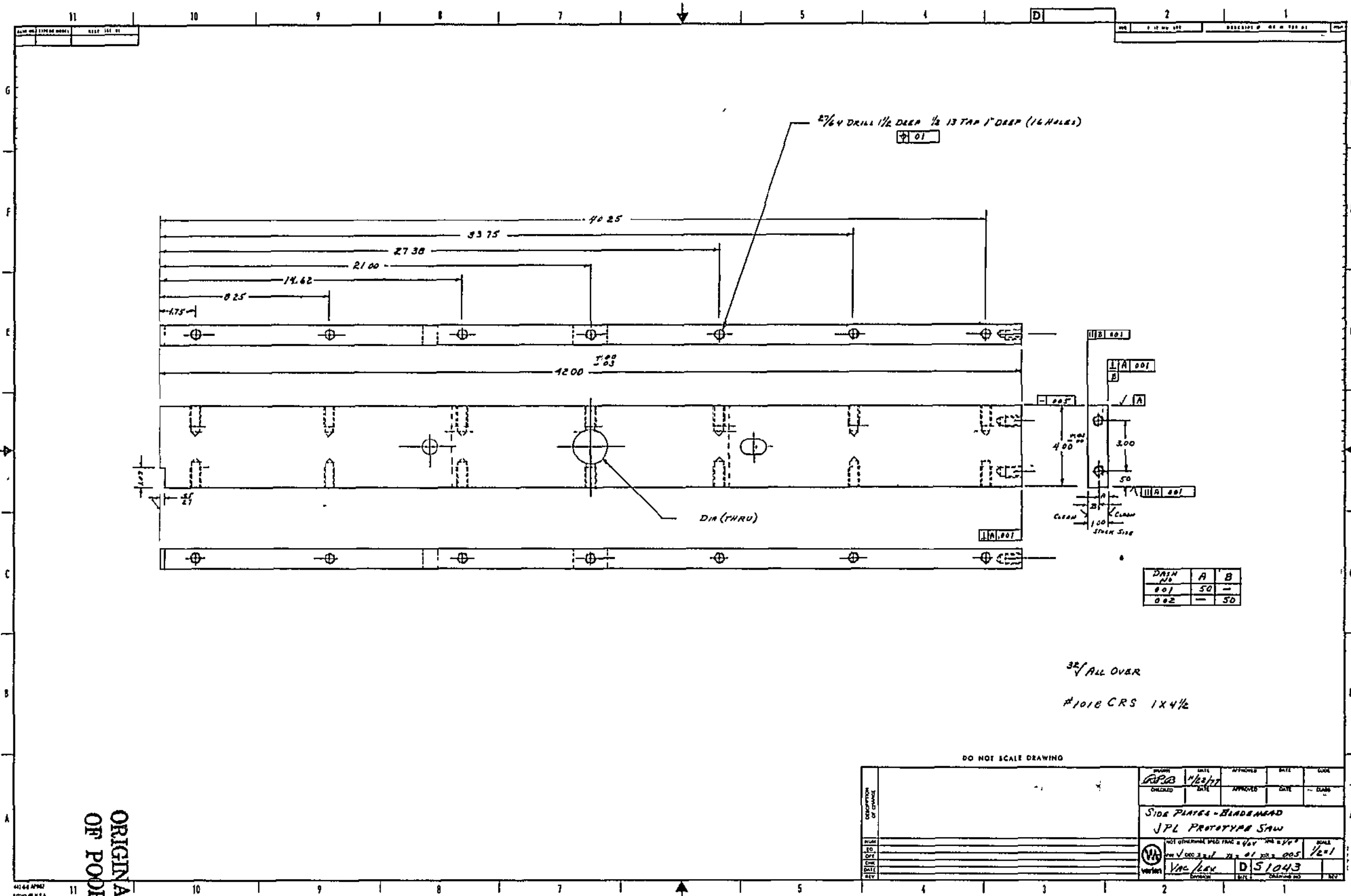
DRAWN	DATE	APPROVED	DATE	CODE
[illegible]	11/28/77			
CHECKED	DATE	APPROVED	DATE	CLASS

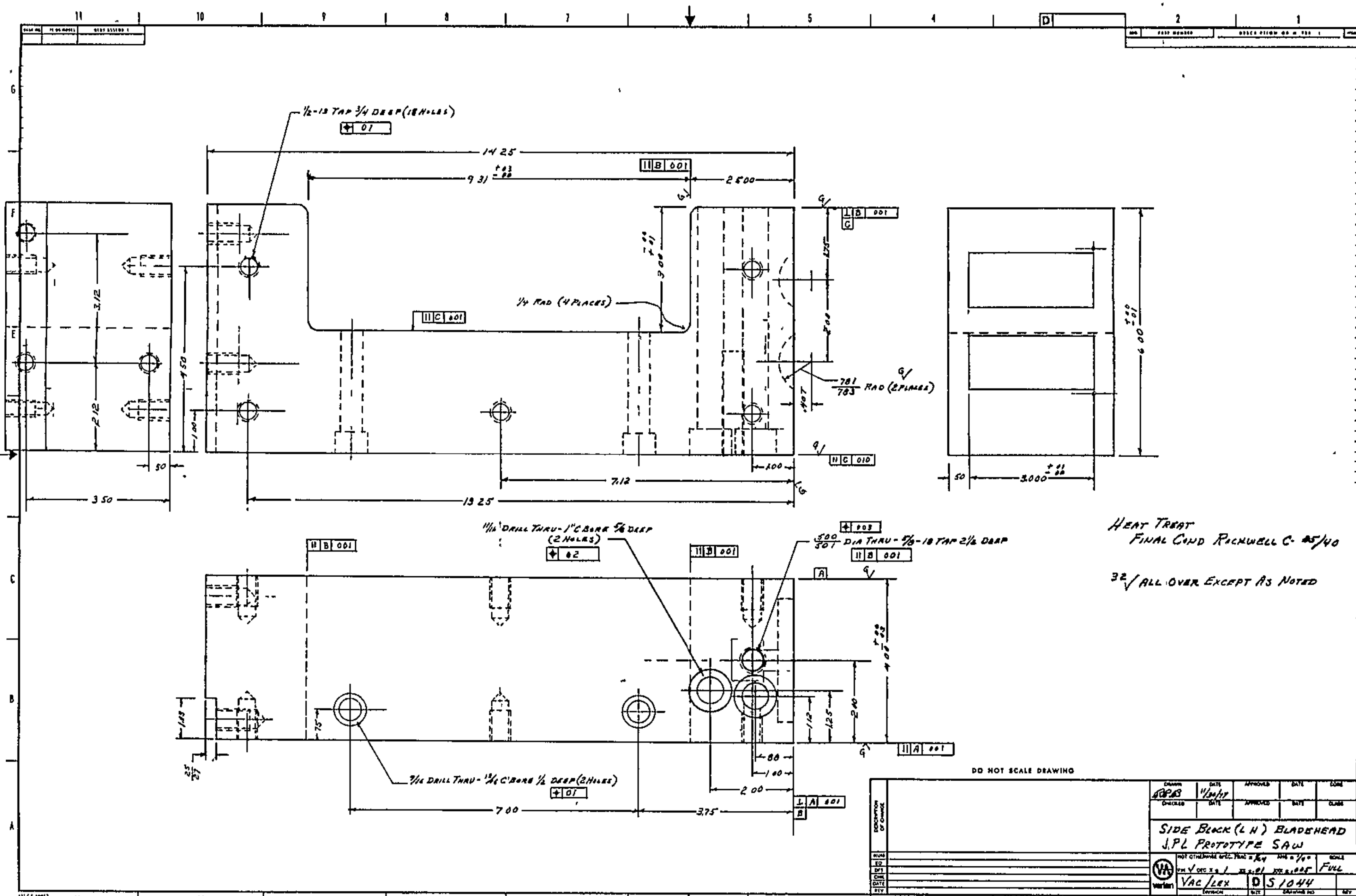
TOP SIDE PLATES (BLADEHEAD)

JPL PROTOTYPE SAW

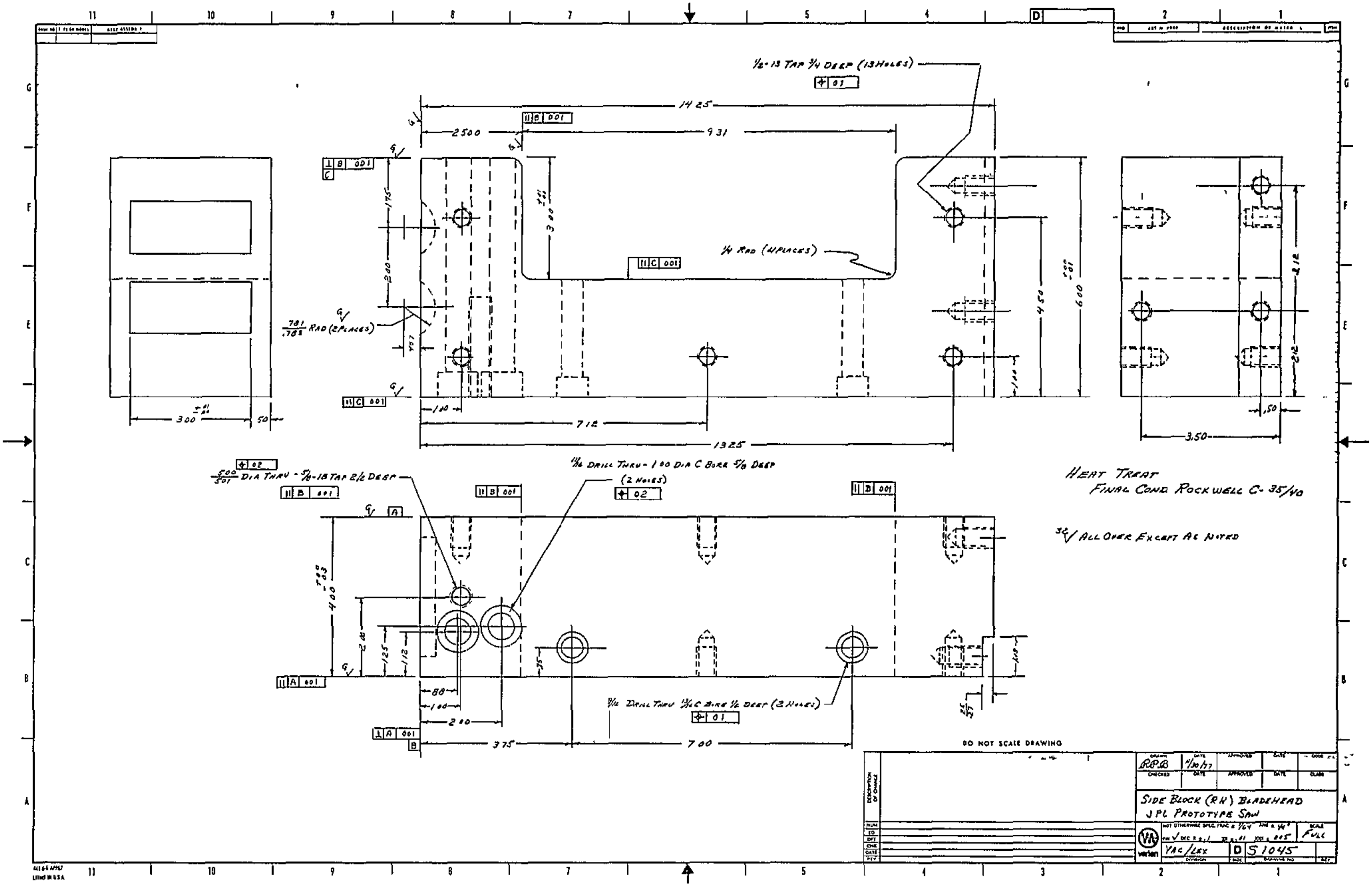
NOT OTHERWISE SPEC FRAC ± 1/64 ANG ± 1/4 — FIN √ DEC ± .1 .XX ± .01 .XXX ± .005 — SCALE 1/2 = 1

varian — VAC/LEX — DIVISION — D — SIZE — S 1042 — DRAWING NO — REV

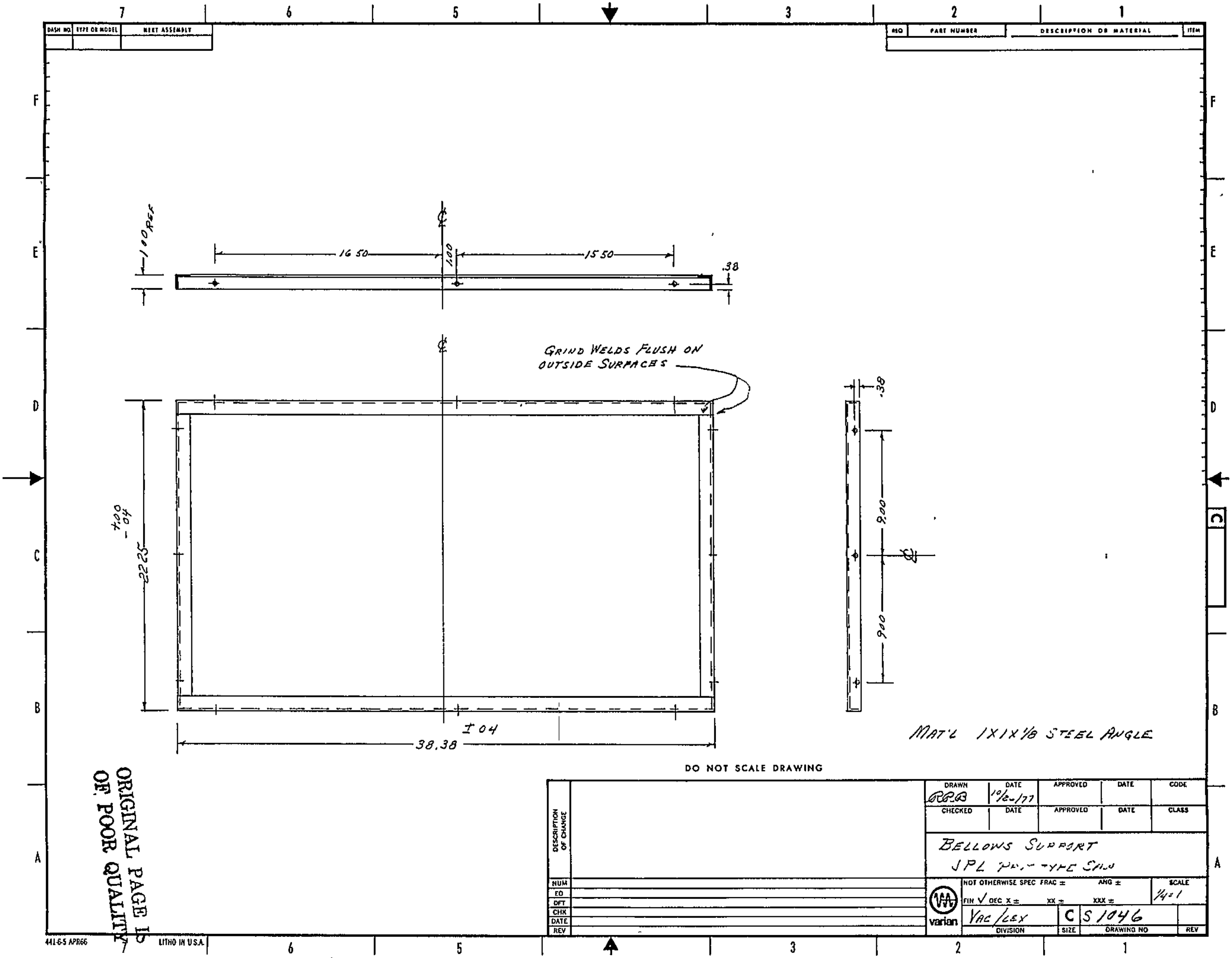

27/64 DRILL 1½ DEEP ½ 13 TAP 1" DEEP (16 HOLES)
40.25
33.75
27.38
21.00
14.62
8.25
1.75
12.00
DIA (THRU)
4.00
3.00
.50
1.00
CLEAN
STOCK SIZE
DASH NO | A | B
001 | .50 | —
002 | — | .50
32/ ALL OVER
#1018 CRS 1X4½
DO NOT SCALE DRAWING
SIDE PLATES - BLADEHEAD
JPL PROTOTYPE SAW
D 51043
1/2=1



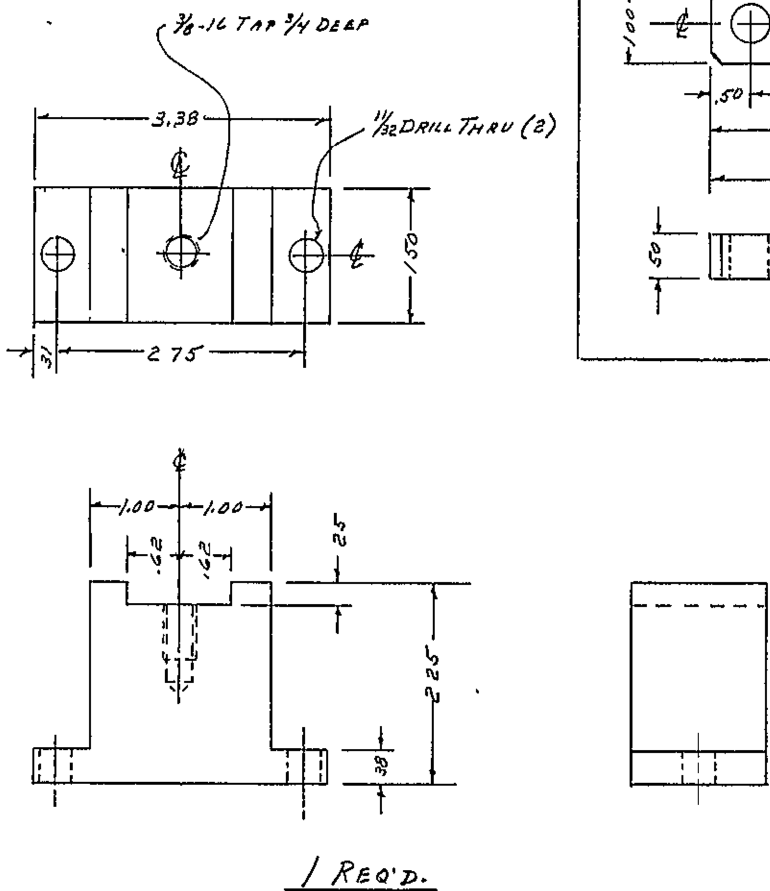
1/2-13 TAP 3/4 DEEP (18 HOLES)
14.25
9.31
2.500
1/4 RAD (4 PLACES)
.781/.783 RAD (2 PLACES)
3.12
2.12
4.50
1.00
3.50
.50
7.12
13.25
3.000
6.00
11/16 DRILL THRU - 1" C'BORE 5/8 DEEP (2 HOLES)
.500/.501 DIA THRU - 5/8-18 TAP 2 1/2 DEEP
9/16 DRILL THRU - 13/16 C'BORE 1/2 DEEP (2 HOLES)
7.00
3.75
2.00
4.00
2.10
HEAT TREAT
FINAL COND ROCKWELL C- 35/40
32√ ALL OVER EXCEPT AS NOTED
DO NOT SCALE DRAWING
SIDE BLOCK (L H) BLADEHEAD
J.P.L PROTOTYPE SAW
FULL
VAC / LEX
D
S 1044

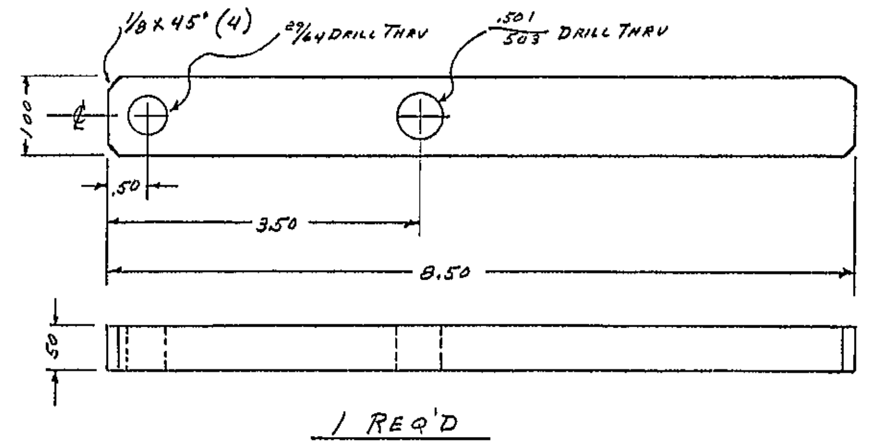


1/2-13 TAP 3/4 DEEP (13 HOLES)
14.25
2.500
9.31
1/4 RAD (4 PLACES)
.781/.782 RAD (2 PLACES)
3.00
4.50
6.00
7.12
13.25
3.50
2.12
HEAT TREAT
FINAL COND ROCKWELL C-35/40
32√ ALL OVER EXCEPT AS NOTED
.500/.501 DIA THRU - 5/8-18 TAP 2 1/2 DEEP
11/16 DRILL THRU - 1.00 DIA C BORE 5/8 DEEP (2 HOLES)
9/16 DRILL THRU 15/16 C BORE 1/2 DEEP (2 HOLES)
3.75
7.00
DO NOT SCALE DRAWING
RPB
11/30/77
SIDE BLOCK (RH) BLADEHEAD
JPL PROTOTYPE SAW
FULL
VAC/LEX
D
S1045
varian



DASH NO.
TYPE OR MODEL
NEXT ASSEMBLY
REQ
PART NUMBER
DESCRIPTION OR MATERIAL
ITEM
1.00 REF
16.50
1.00
15.50
.38
GRIND WELDS FLUSH ON OUTSIDE SURFACES
+.00
-.04
22.25
1.04
38.38
.38
9.00
9.00
MAT'L 1X1X1/8 STEEL ANGLE
DO NOT SCALE DRAWING
DESCRIPTION OF CHANGE
NUM
EO
DFT
CHK
DATE
REV
DRAWN
RRB
DATE
10/2-/77
APPROVED
DATE
CODE
CHECKED
DATE
APPROVED
DATE
CLASS
BELLOWS SUPPORT
JPL
NOT OTHERWISE SPEC FRAC ±
ANG ±
SCALE
1/4=1
FIN √ DEC X ±
XX ±
XXX ±
varian
VAC/LEX
DIVISION
C
SIZE
S 1046
DRAWING NO
REV
441-6-5 APR66
LITHO IN U.S.A.





DO NOT SCALE DRAWING

DASH NO	TYPE OR MODEL	NEXT ASSEMBLY

REQ	PART NUMBER	DESCRIPTION OR MATERIAL	ITEM

DRAWN	DATE	APPROVED	DATE	CODE
RPB	12/14/77			
CHECKED	DATE	APPROVED	DATE	CLASS

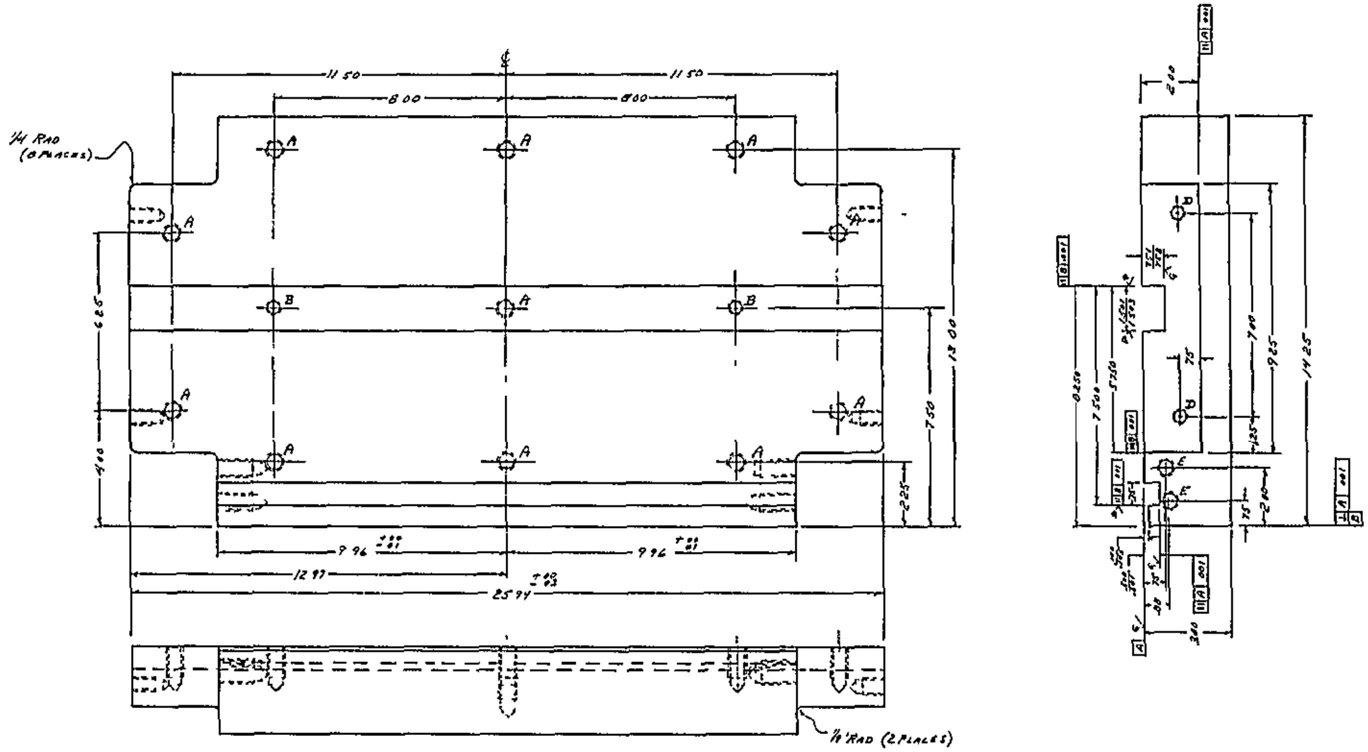
SPEED SHIFT PARTS
JPL PROTOTYPE SAW

NOT OTHERWISE SPEC FRAC ± 1/64 ANG ± 1/4° FIN √ DEC X ± .1 XX ± .02 XXX ± .005 — SCALE FULL

varian — VAC/LEX (DIVISION) — SIZE C — DRAWING NO S 1047 — REV

DESCRIPTION OF CHANGE — NUM / EO / DFT / CHK / DATE / REV

441-6-5 APR66 LITHO IN U.S.A.



A = 5/8 11 TAP - 1.00 DEEP (11 HOLES) ⌖ .02
B = 1/2-13 TAP 3/4 DEEP (NEAR SIDE) (2 HOLES) ⌖ .01
C = —
D = 1/2 13 TAP 3/4 DEEP (4 HOLES) ⌖ .01
E = 5/8 18 TAP 1 1/4 DEEP (4 HOLES) ⌖ .01

NOTE - HEAT TREAT
FINAL COND ROCKWELL C - 35/40

32√ EXCEPT AS NOTED

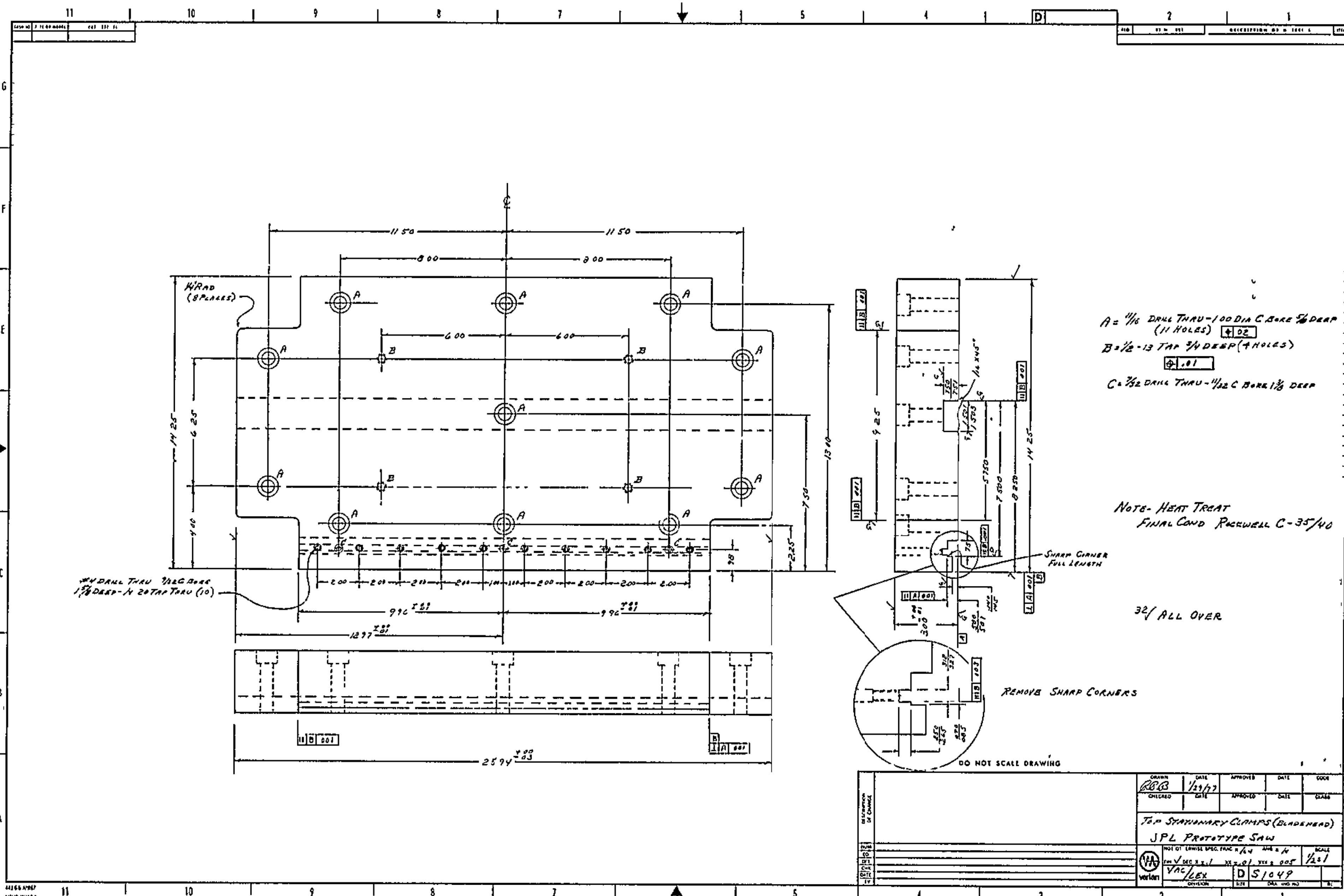
REMOVE SHARP CORNERS EXCEPT AS NOTED

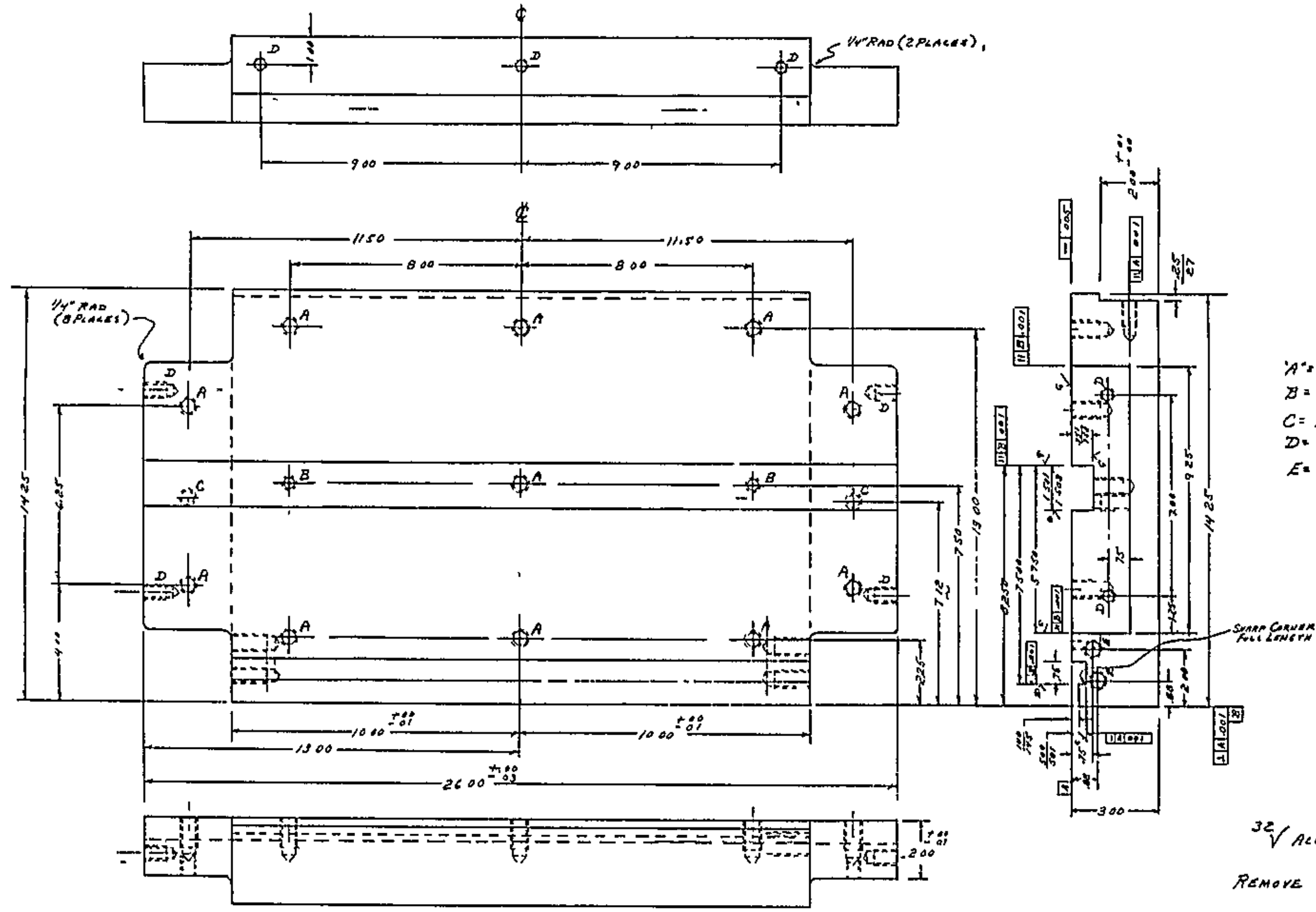
DO NOT SCALE DRAWING

DRAWN	DATE	APPROVED	DATE	CODE
RSB	12/13/77			
CHECKED	DATE	APPROVED	DATE	CLASS

BOTTOM MOVING CLAMP - BLADEHEAD
JPL PROTOTYPE SAW

NOT OTHERWISE SPEC. FRAC ± 1/64 ANG ± 1/2 — SCALE 1/2 = 1
DEC X ± .1 XX ± .02 XXX ± .005
varian — VAC/LEX — D — 51048


1/4 RAD (8 PLACES)
A = 11/16 DRILL THRU - 1.00 DIA C BORE 5/8 DEEP (11 HOLES)
B = 1/2-13 TAP 3/4 DEEP (4 HOLES)
C = 7/32 DRILL THRU - 11/32 C BORE 1 1/8 DEEP
NOTE- HEAT TREAT FINAL COND ROCKWELL C-35/40
32/ ALL OVER
#4 DRILL THRU 7/32 C BORE 1 5/8 DEEP - 1/4 20 TAP THRU (10)
SHARP CORNER FULL LENGTH
REMOVE SHARP CORNERS
DO NOT SCALE DRAWING
TOP STATIONARY CLAMPS (BLADEHEAD)
JPL PROTOTYPE SAW
1/29/77
1/2 = 1
VAC/LEX
D S1049
varian



'A' = 5/8 11 TAP 1.00 DEEP (11 HOLES) ⌖ .02
B = 1/2-13 TAP 3/4 DEEP (NEAR SIDE) (2 HOLES) ⌖ .01
C = 1/2 13 TAP 3/4 DEEP (FAR SIDE) (2 HOLES) ⌖ .01
D = 1/2 13 TAP 3/4 DEEP (7 HOLES) ⌖ .01
E = 5/8-18 TAP 1 1/4 DEEP (4 HOLES) ⌖ .02

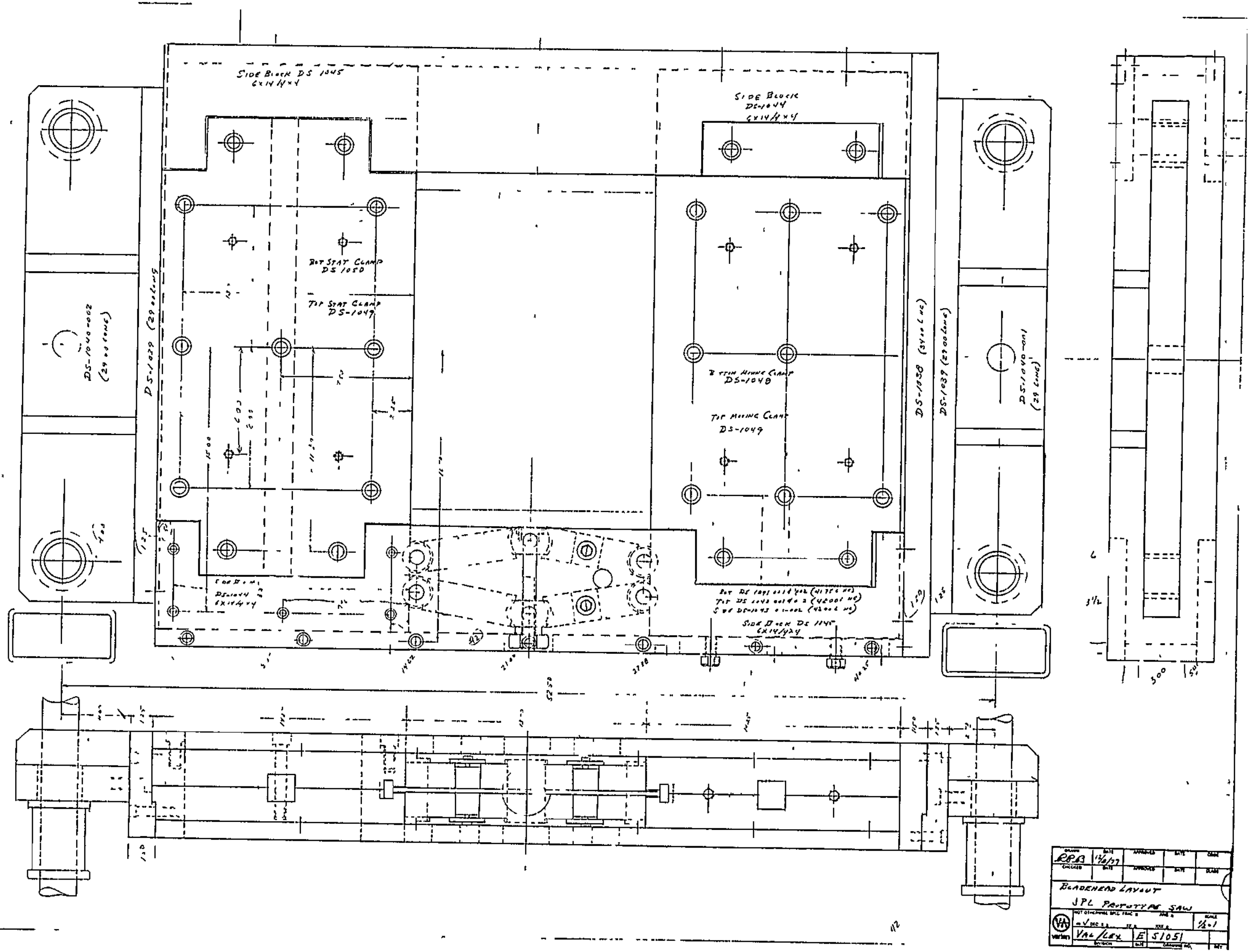
NOTE HEAT TREAT
FINAL COND. ROCKWELL C-35/40

32√ ALL OVER EXCEPT AS NOTED

REMOVE SHARP CORNERS EXCEPT AS NOTED

DO NOT SCALE DRAWING

DRAWN	BPB
DATE	11/29/77
TITLE	BOTTOM STATIONARY CLAMP (BLADEHEAD) JPL PROTOTYPE SAW
SCALE	1/2 = 1
DIVISION	VAC/LEC
SIZE	D
DRAWING NO	S1050

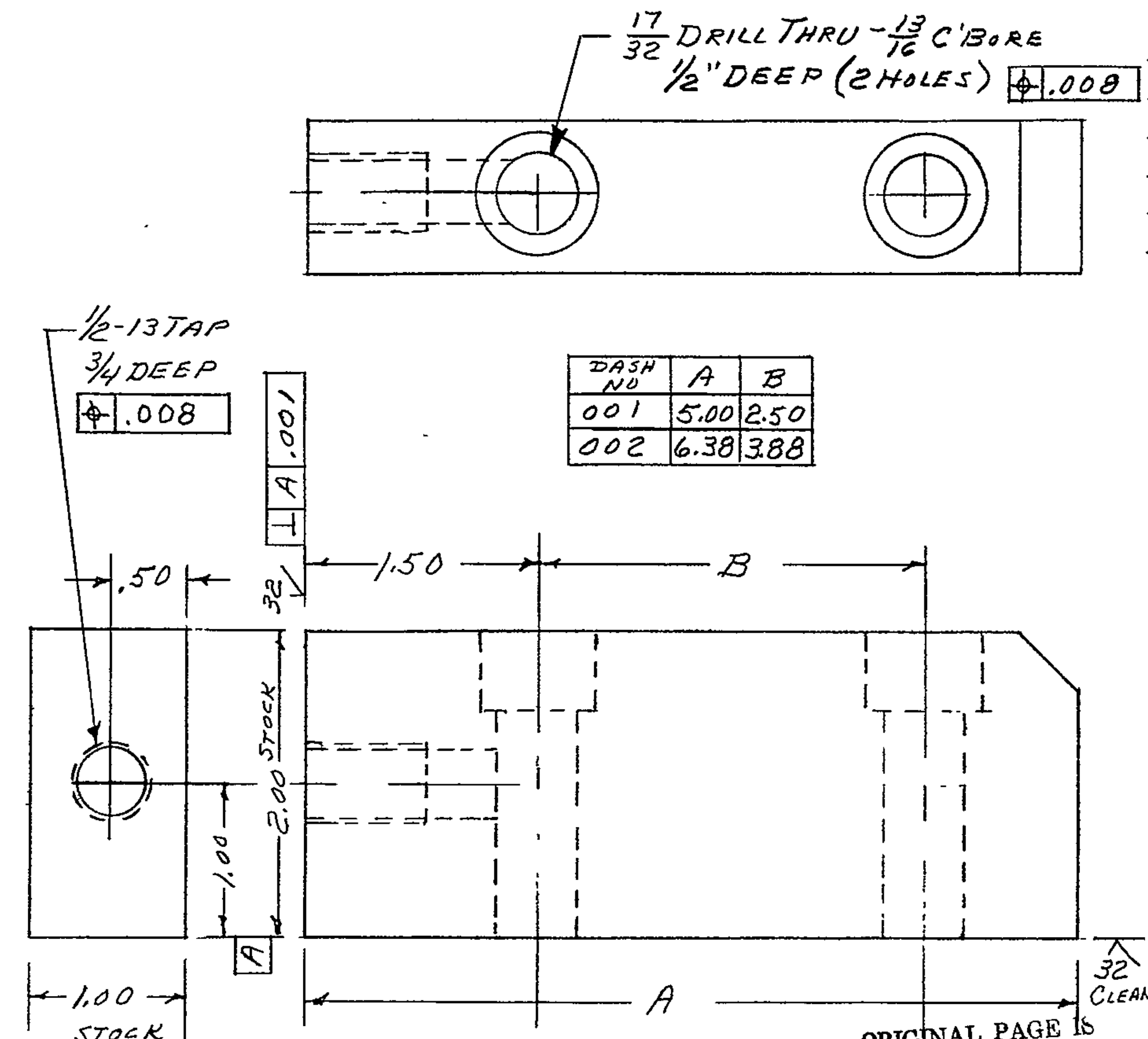


SIDE BLOCK DS 1045
6x14 1/4x4
SIDE BLOCK
DS-1044
6x14 1/4x4
BOT STAT CLAMP
DS 1050
TOP STAT CLAMP
DS-1049
TOP MOVING CLAMP
DS-1049
DS-1040-002
(29.00 LONG)
DS-1039 (29.00 LONG)
DS-1038
DS-1039 (29.00 LONG)
DS-1040-001
(29 LONG)
SIDE BLOCK DS 1045
6x14 1/4x24
5250
300
RPB
12/8/77
BLADEHEAD LAYOUT
JPL PROTOTYPE SAW
1/2:1
varian
VAL/LEX
E
51051

DASH NO	TYPE OR MODEL	NEXT ASSEMBLY	REQ	PART NUMBER	DESCRIPTION OR MATERIAL

A S1052

DO NOT SCALE DRAWING



DASH NO	A	B
001	5.00	2.50
002	6.38	3.88

ORIGINAL PAGE IS OF POOR QUALITY

DO NOT SCALE THIS PRINT
UNLESS OTHERWISE SPECIFIED
BREAK ALL SHARP EDGES
DIMENSIONS ARE IN INCHES

DRAWN	DATE	APPROVED	DATE	CODE
RPB	11/17/77			
CHECKED	DATE	APPROVED	DATE	CLASS

GUSSETS - BLADE HEAD
JPL PROTOTYPE SAW

NOT OTHERWISE SPEC. FRAC ± ANG ± SCALE FULL
FIN √ DEC .X ± .XX ± .XXX ±

varian

DIVISION	SIZE	DRAWING NO.	REV
VAC/LEX	A	S1052	

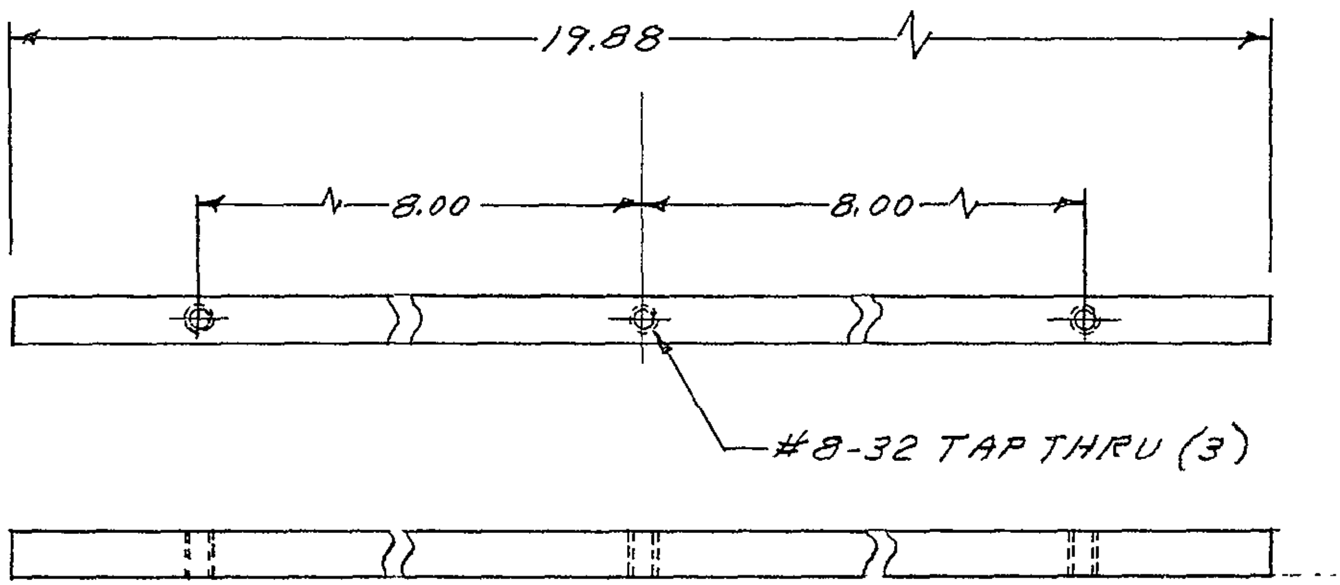
DESCRIPTION OF CHANGE

NUM	
EO	
DFT	
CHK	
DATE	
REV	

DASH NO	TYPE OR MODEL	NEXT ASSEMBLY	REQ	PART NUMBER	DESCRIPTION OR MATERIAL	ITEM

A 51053

DO NOT SCALE DRAWING



MAT'L - 1/4" SAE 1020 KEYSTOCK
(2 REQ'D)

DO NOT SCALE THIS PRINT
UNLESS OTHERWISE SPECIFIED
BREAK ALL SHARP EDGES
DIMENSIONS ARE IN INCHES

DRAWN	DATE	APPROVED	DATE	CODE
RPB	12/16/77			
CHECKED	DATE	APPROVED	DATE	CLASS

SMALL BLADEHEAD KEY
JPL PROTOTYPE SAW

NOT OTHERWISE SPEC FRAC ± 1/64 ANG ± 1/4° | SCALE ~

FIN √ DEC X ± .1 XX ± .02 XXX ± .005

varian

DIVISION	SIZE	DRAWING NO	REV
VAC/LEX	A	51053	

DESCRIPTION OF CHANGE

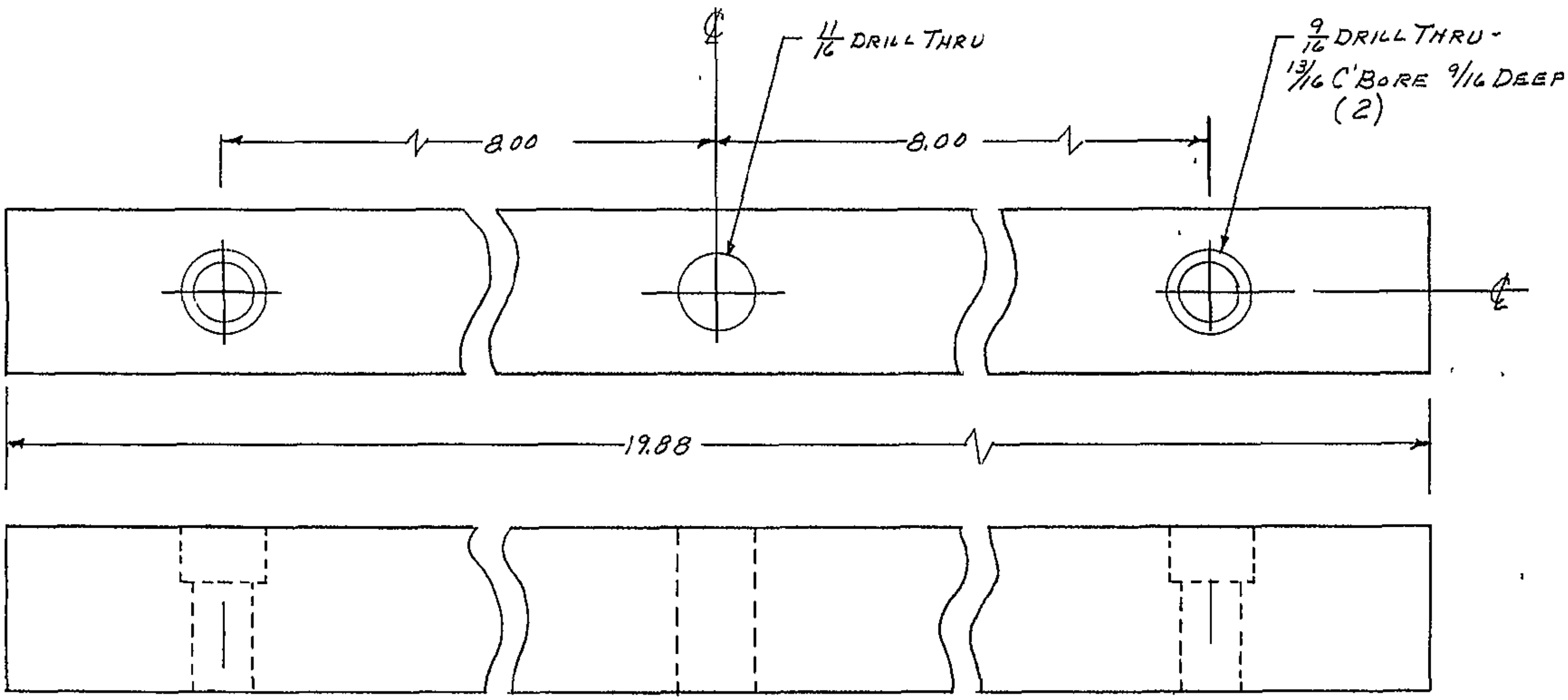
NUM	
EO	
DFT	
CHK	
DATE	
REV	

LITHO IN U.S.A.

441-6-1

DASH NO	TYPE OR MODEL	NEXT ASSEMBLY

REQ	PART NUMBER	DESCRIPTION OR MATERIAL	ITEM



DO NOT SCALE DRAWING

MAT'L - 1 1/2" SAE 1020 KEYSTOCK

DO NOT SCALE THIS PRINT
UNLESS OTHERWISE SPECIFIED
BREAK ALL SHARP EDGES
DIMENSIONS ARE IN INCHES

DESCRIPTION OF CHANGE

NUM / ED / DIT / CHK / DATE / REV

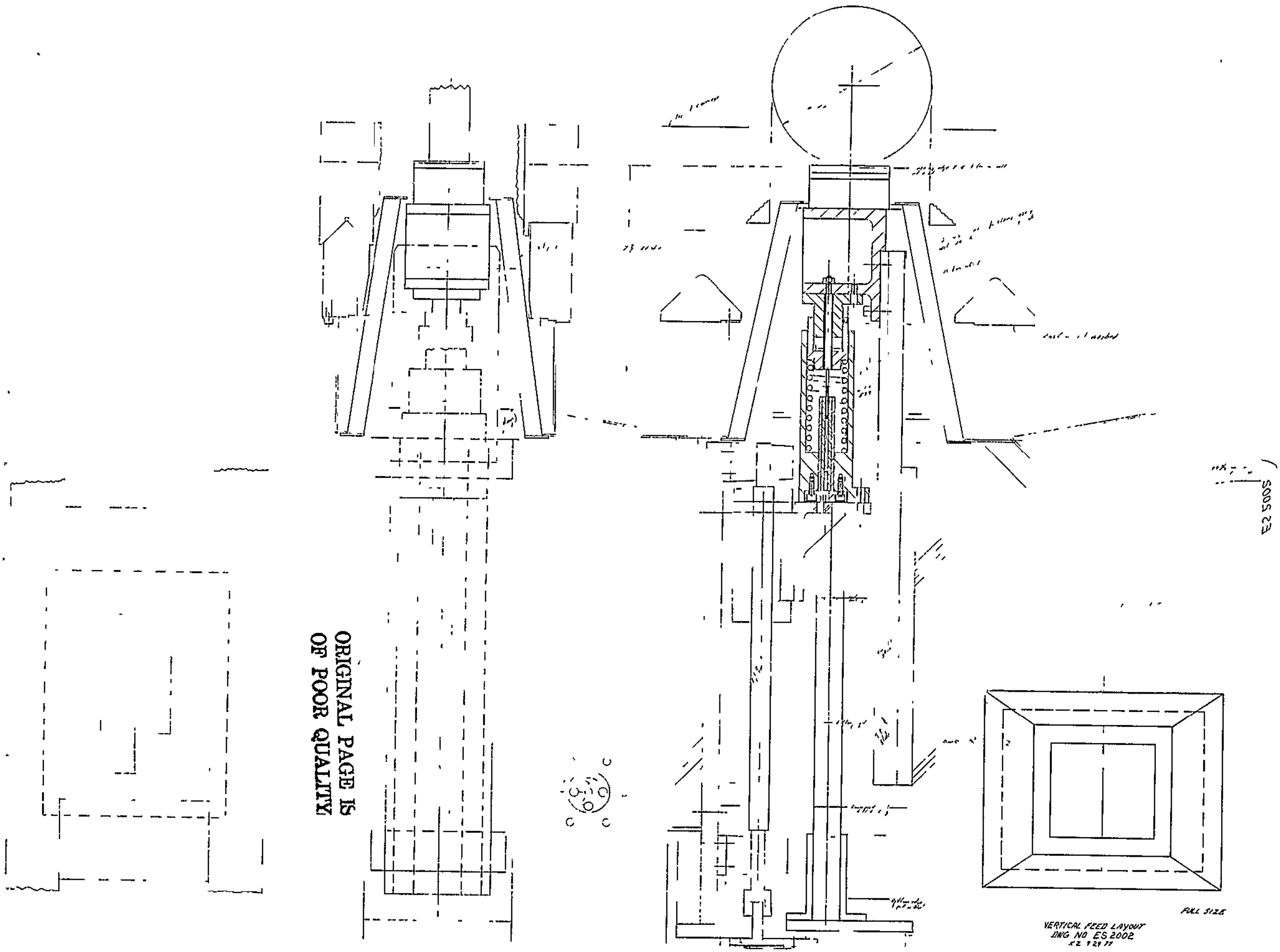
DRAWN	DATE	APPROVED	DATE	CODE
RCB	12/16/77			
CHECKED	DATE	APPROVED	DATE	CLASS

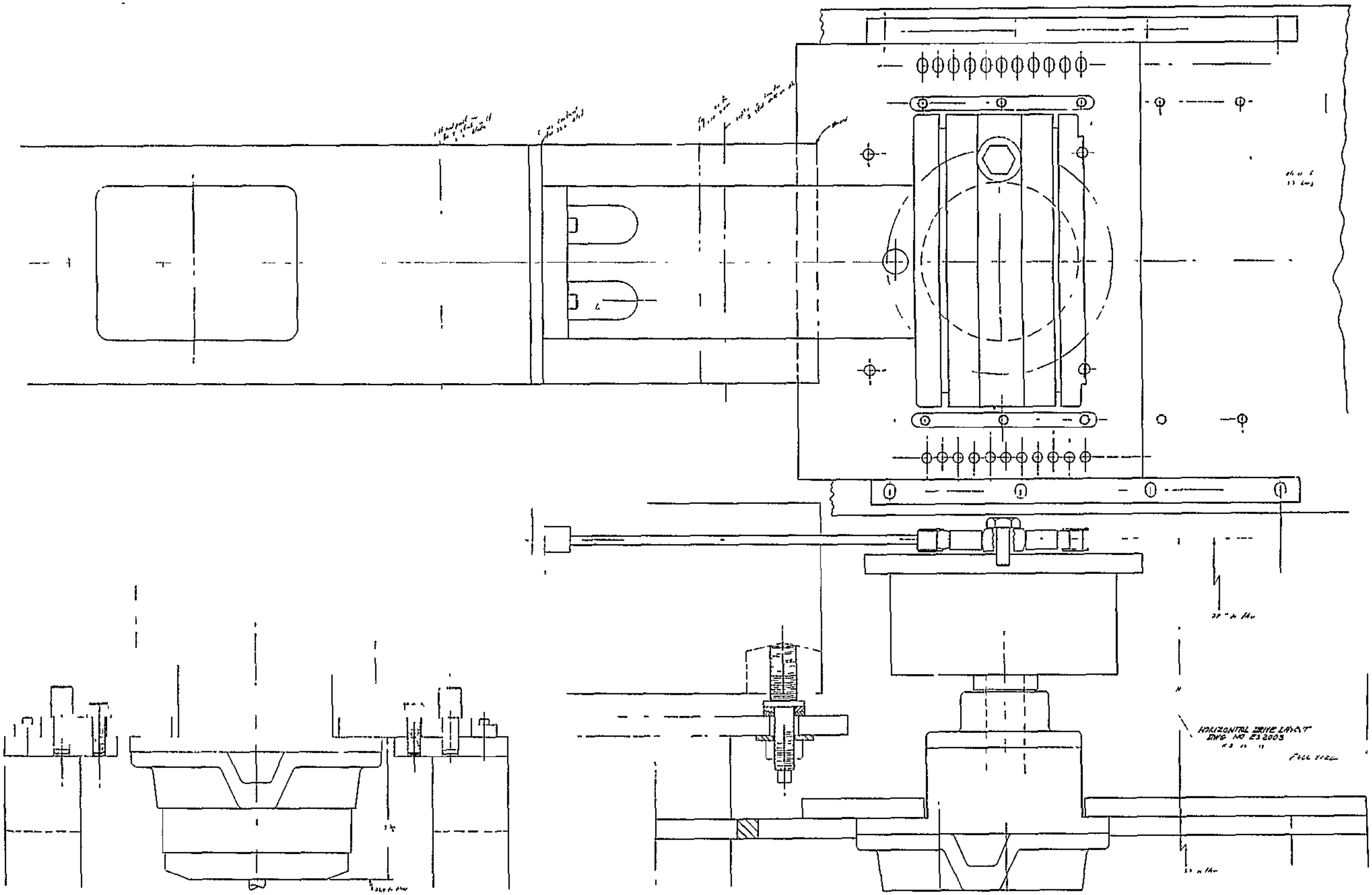
LARGE BLADEHEAD KEY
JPL PROTOTYPE SAW

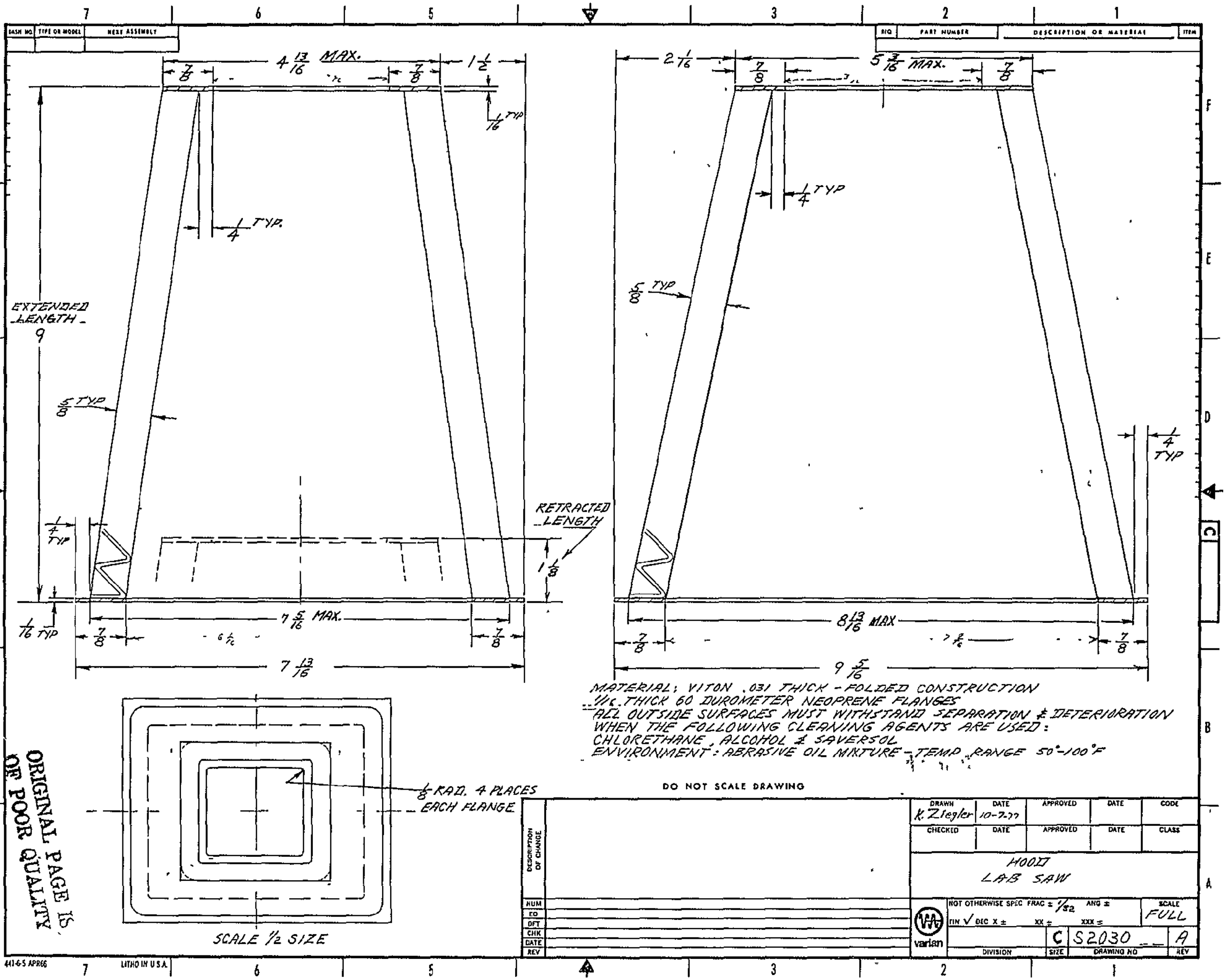
NOT OTHERWISE SPEC FRAC ± 1/64 ANG ± 1/4° SCALE ~
FIN √ DEC X ± .1 XX ± .02 XXX ± .005

varian

DIVISION	SIZE	DRAWING NO	REV
VAC/LEX	B	S1054	


FULL SIZE
VERTICAL FEED LAYOUT
DWG NO ES 2002


HORIZONTAL DRIVE LAYOUT
DWG NO ES2005

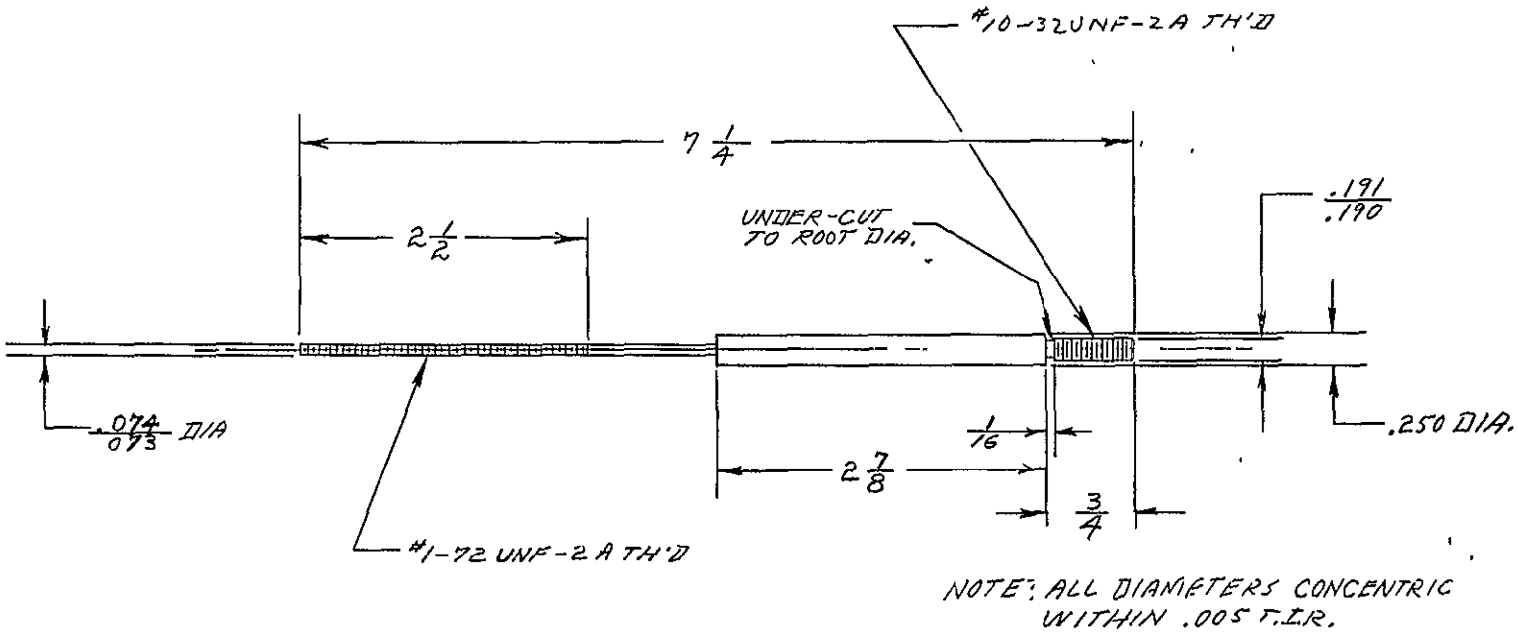


DASH NO.
TYPE OR MODEL
NEXT ASSEMBLY
REQ
PART NUMBER
DESCRIPTION OR MATERIAL
ITEM
4 13/16 MAX.
7/8
7/8
1 1/2
1/16 TYP
1/4 TYP.
EXTENDED LENGTH 9
5/8 TYP
1/4 TYP
RETRACTED LENGTH
1 1/8
1/16 TYP
7 5/16 MAX.
7/8
7/8
7 13/16
2 1/16
5 3/16 MAX.
7/8
7/8
1/4 TYP
5/8 TYP
1/4 TYP
8 13/16 MAX
7/8
7/8
9 5/16
MATERIAL: VITON .031 THICK - FOLDED CONSTRUCTION
1/16 THICK 60 DUROMETER NEOPRENE FLANGES
ALL OUTSIDE SURFACES MUST WITHSTAND SEPARATION & DETERIORATION
WHEN THE FOLLOWING CLEANING AGENTS ARE USED:
CHLORETHANE, ALCOHOL & SAVERSOL
ENVIRONMENT: ABRASIVE OIL MIXTURE - TEMP RANGE 50°-100°F
1/8 RAD. 4 PLACES EACH FLANGE
SCALE 1/2 SIZE
DO NOT SCALE DRAWING
DESCRIPTION OF CHANGE
NUM
EO
DFT
CHK
DATE
REV
DRAWN K. Ziegler
DATE 10-7-77
APPROVED
DATE
CODE
CHECKED
DATE
APPROVED
DATE
CLASS
HOOD
LAB SAW
NOT OTHERWISE SPEC FRAC ± 1/32 ANG ±
FIN √ DEC X ± XX ± XXX ±
SCALE FULL
varian
DIVISION
SIZE C
DRAWING NO S2030
REV A
441-6-5 APR66
LITHO IN U.S.A.

DASH NO	TYPE OR MODEL	NEXT ASSEMBLY

REQ	PART NUMBER	DESCRIPTION OR MATERIAL	ITEM
	1		

DO NOT SCALE DRAWING



DO NOT SCALE THIS PRINT
UNLESS OTHERWISE SPECIFIED
BREAK ALL SHARP EDGES
DIMENSIONS ARE IN INCHES

DESCRIPTION OF CHANGE

NUM | EO | DFT | CHK | DATE | REV

DRAWN	DATE	APPROVED	DATE	CODE
K Z.	10-13-77			
CHECKED	DATE	APPROVED	DATE	CLASS

PUSH ROD
LAB. SAW

NOT OTHERWISE SPEC FRAC ± 1/64 ANG ± 1/2° SCALE FULL
FIN 63√ DEC X ± XX ± .01 XXX ± .005

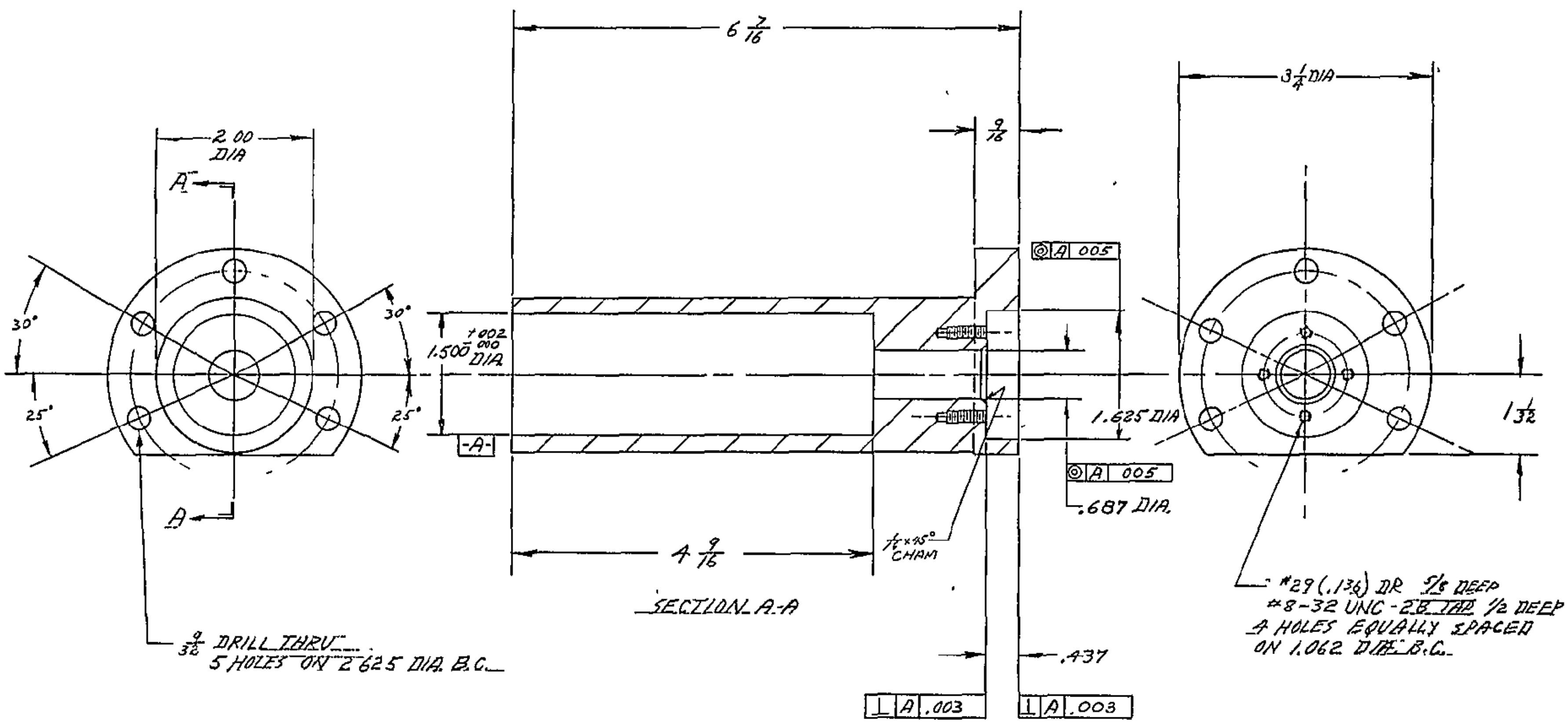
varian

DIVISION	SIZE	DRAWING NO	REV
	B	52031	

44164 JUNE66 LITHO IN U S A

DASH NO.	TYPE OR MODEL	NEXT ASSEMBLY

REQ	PART NUMBER	DESCRIPTION OR MATERIAL	ITEM



DO NOT SCALE DRAWING

DRAWN	DATE	APPROVED	DATE	CODE
KZ	10-10-77			
CHECKED	DATE	APPROVED	DATE	CLASS

SPRING HOUSING
LAB. SAW

DESCRIPTION OF CHANGE

NUM / EO / DFT / CHK / DATE / REV

NOT OTHERWISE SPEC FRAC ± 1/64 ANG ± 1/2° FIN 63 DEC X ± XX ± .01 XXX ± .005 | SCALE FULL

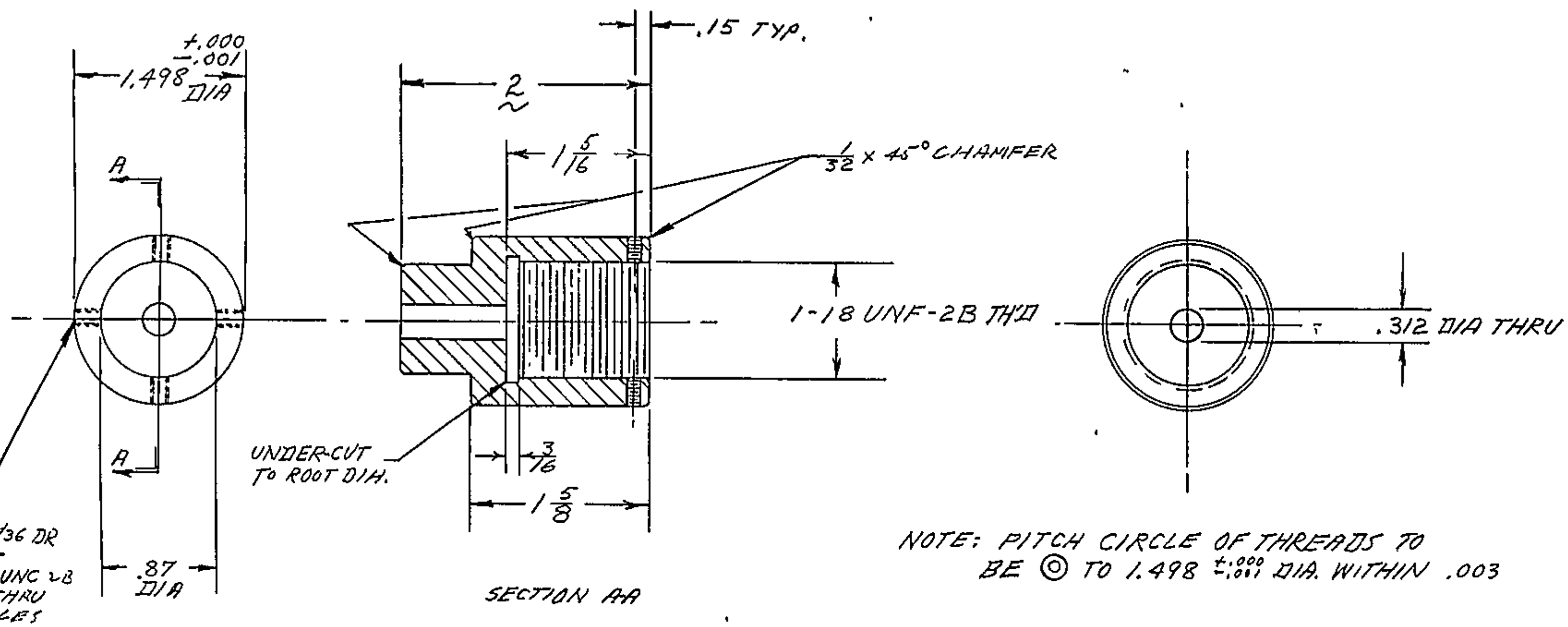
varian | DIVISION | SIZE C | DRAWING NO S 2032 | REV

441-6-5 APR66 LITHO IN U.S.A.

DASH NO	TYPE OR MODEL	NEXT ASSEMBLY

REQ	PART NUMBER	DESCRIPTION OR MATERIAL	ITEM

DO NOT SCALE DRAWING



NOTE: PITCH CIRCLE OF THREADS TO BE ◎ TO 1.498 +.000 −.001 DIA. WITHIN .003

DO NOT SCALE THIS PRINT
UNLESS OTHERWISE SPECIFIED
BREAK ALL SHARP EDGES
DIMENSIONS ARE IN INCHES

DESCRIPTION OF CHANGE

NUM	
EO	
DFT	
CHK	
DATE	
REV	

DRAWN	DATE	APPROVED	DATE	CODE
KZ	10-10-77			
CHECKED	DATE	APPROVED	DATE	CLASS

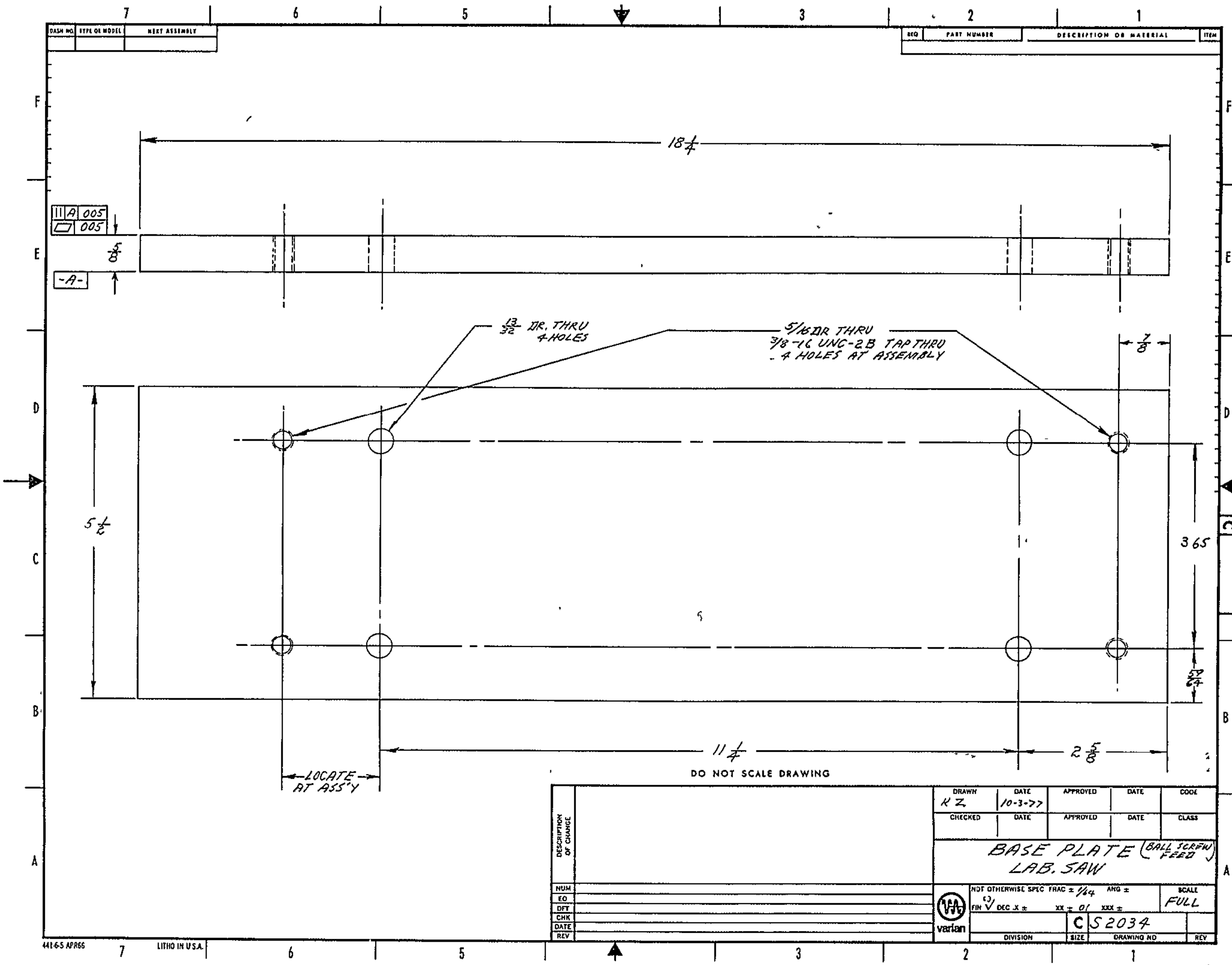
NUT
LAB. SAW

NOT OTHERWISE SPEC FRAC ± 1/64 ANG ±
FIN 63√ DEC X ± XX ± .01 XXX ± .005

SCALE FULL

varian

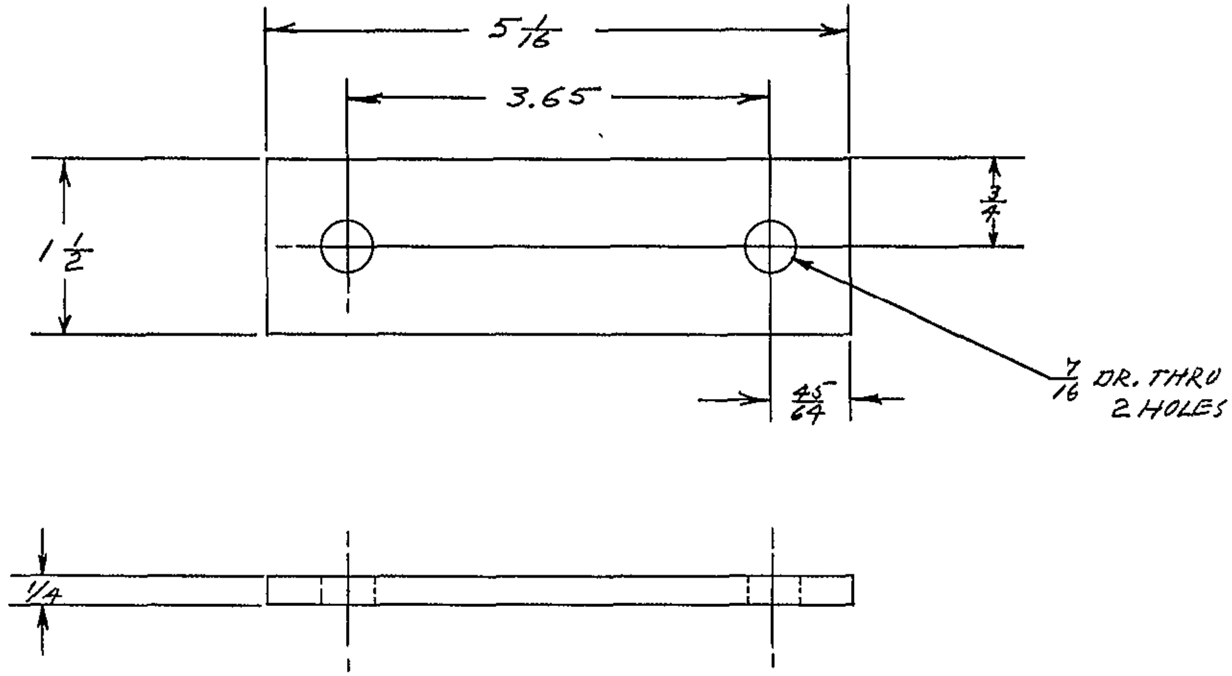
DIVISION	SIZE	DRAWING NO	REV
	B	52033	



DASH NO.
TYPE OR MODEL
NEXT ASSEMBLY
REQ
PART NUMBER
DESCRIPTION OR MATERIAL
ITEM
18 1/4
A .005
.005
5/8
-A-
13/32 DR. THRU
4 HOLES
5/16 DR THRU
3/8-16 UNC-2B TAP THRU
4 HOLES AT ASSEMBLY
7/8
5 1/2
3.65
57/64
11 1/4
2 5/8
LOCATE AT ASS'Y
DO NOT SCALE DRAWING
DESCRIPTION OF CHANGE
NUM
EO
DFT
CHK
DATE
REV
DRAWN
KZ
DATE
10-3-77
CHECKED
APPROVED
CODE
CLASS
BASE PLATE (BALL SCREW FEED)
LAB. SAW
NOT OTHERWISE SPEC FRAC ± 1/64 ANG ±
DEC .X ± .XX ± .01 .XXX ±
SCALE
FULL
varian
C
S 2034
DIVISION
SIZE
DRAWING NO
REV
441-6-5 APR66
LITHO IN U.S.A.

DASH NO	TYPE OR MODEL	NEXT ASSEMBLY

REQ	PART NUMBER	DESCRIPTION OR MATERIAL	ITEM



DO NOT SCALE DRAWING

DO NOT SCALE THIS PRINT
UNLESS OTHERWISE SPECIFIED
BREAK ALL SHARP EDGES
DIMENSIONS ARE IN INCHES

DESCRIPTION OF CHANGE

NUM / EO / DFT / CHK / DATE / REV

DRAWN	DATE	APPROVED	DATE	CODE
K.Z.	10-10-77			
CHECKED	DATE	APPROVED	DATE	CLASS

PILLOW BLOCK SPACER
LAB. SAW

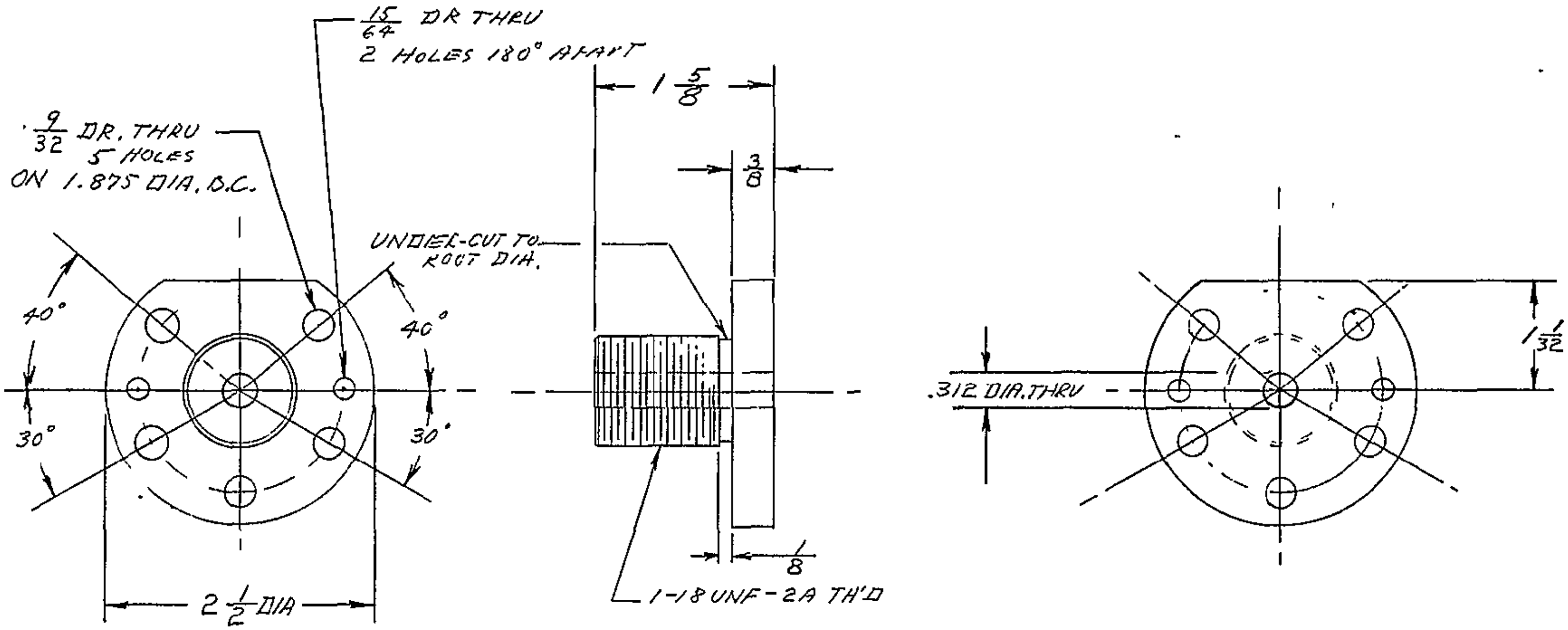
NOT OTHERWISE SPEC FRAC ± 1/64 ANG ±
FIN 63 ∨ DEC X ± XX ± .01 XXX ±

SCALE FULL

varian

DIVISION	SIZE	DRAWING NO	REV
	B	52035	

44164 JUNE66 LITHO IN U S A



DASH NO	TYPE OR MODEL	NEXT ASSEMBLY

REQ	PART NUMBER	DESCRIPTION OR MATERIAL	ITEM

DO NOT SCALE THIS PRINT
UNLESS OTHERWISE SPECIFIED
BREAK ALL SHARP EDGES
DIMENSIONS ARE IN INCHES

DESCRIPTION OF CHANGE

NUM / EO / DFT / CHK / DATE / REV

DRAWN	DATE	APPROVED	DATE	CODE
KZ	10-11-77			
CHECKED	DATE	APPROVED	DATE	CLASS

TAKE-UP SCREW
LAB. SAW

NOT OTHERWISE SPEC FRAC ± 1/64 ANG ± 1/2°
FIN 63√ DEC X ± XX ± .01 XXX ± .005

SCALE FULL

varian

DIVISION	SIZE	DRAWING NO	REV
	B	S 2036	

44164 JUNE66 LITHO IN U.S.A.

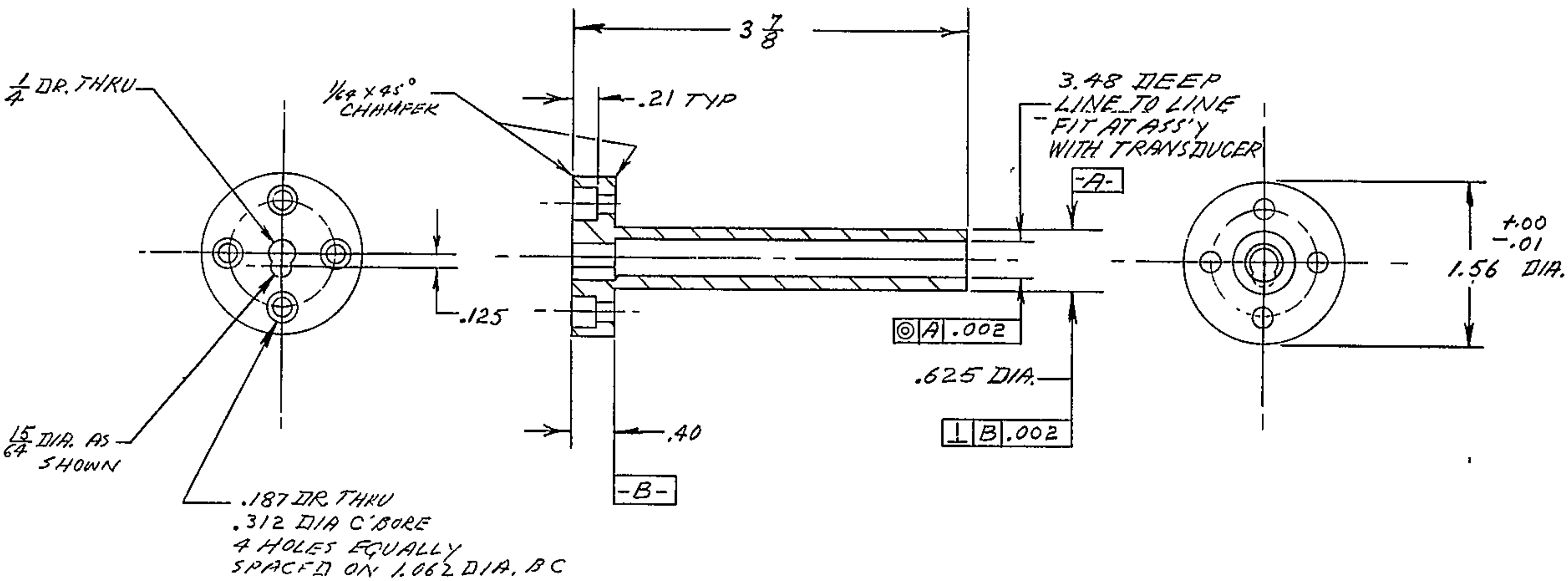
DO NOT SCALE DRAWING

ORIGINAL PAGE IS
OF POOR QUALITY

DASH NO	TYPE OR MODEL	NEXT ASSEMBLY

REQ	PART NUMBER	DESCRIPTION OR MATERIAL	ITEM

DO NOT SCALE DRAWING



DO NOT SCALE THIS PRINT
UNLESS OTHERWISE SPECIFIED
BREAK ALL SHARP EDGES
DIMENSIONS ARE IN INCHES

DESCRIPTION OF CHANGE

NUM / EO / DFT / CHK / DATE / REV

DRAWN	DATE	APPROVED	DATE	CODE
R.Z.	10-13-77			
CHECKED	DATE	APPROVED	DATE	CLASS

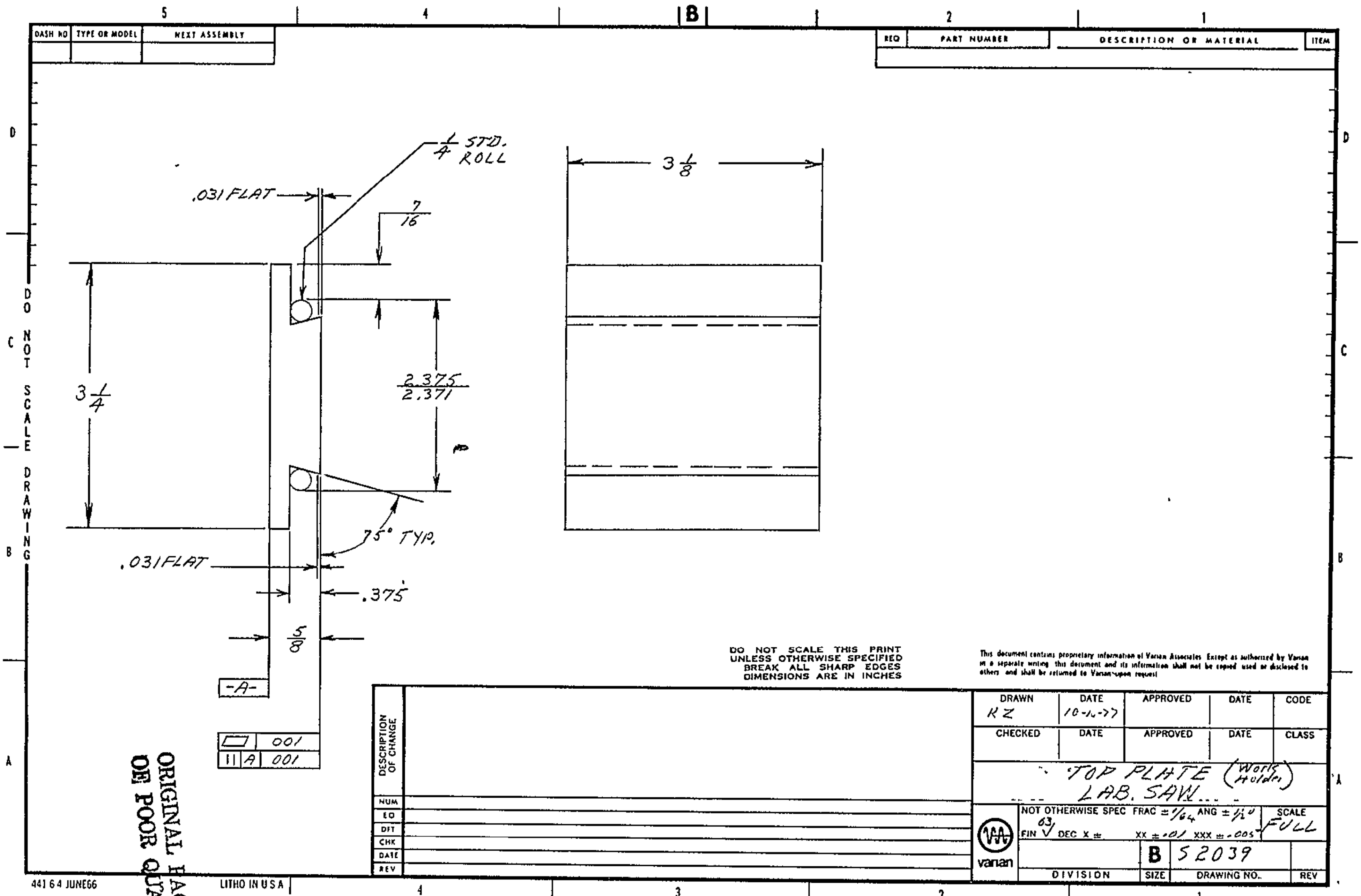
TRANSDUCER SLEEVE
LAB. SAW

NOT OTHERWISE SPEC FRAC ± 1/64 ANG ± 1/2°
FIN 63√ DEC X ± XX ± .01 XXX ± .005

SCALE FULL

varian

DIVISION	SIZE	DRAWING NO	REV
	B	52037	



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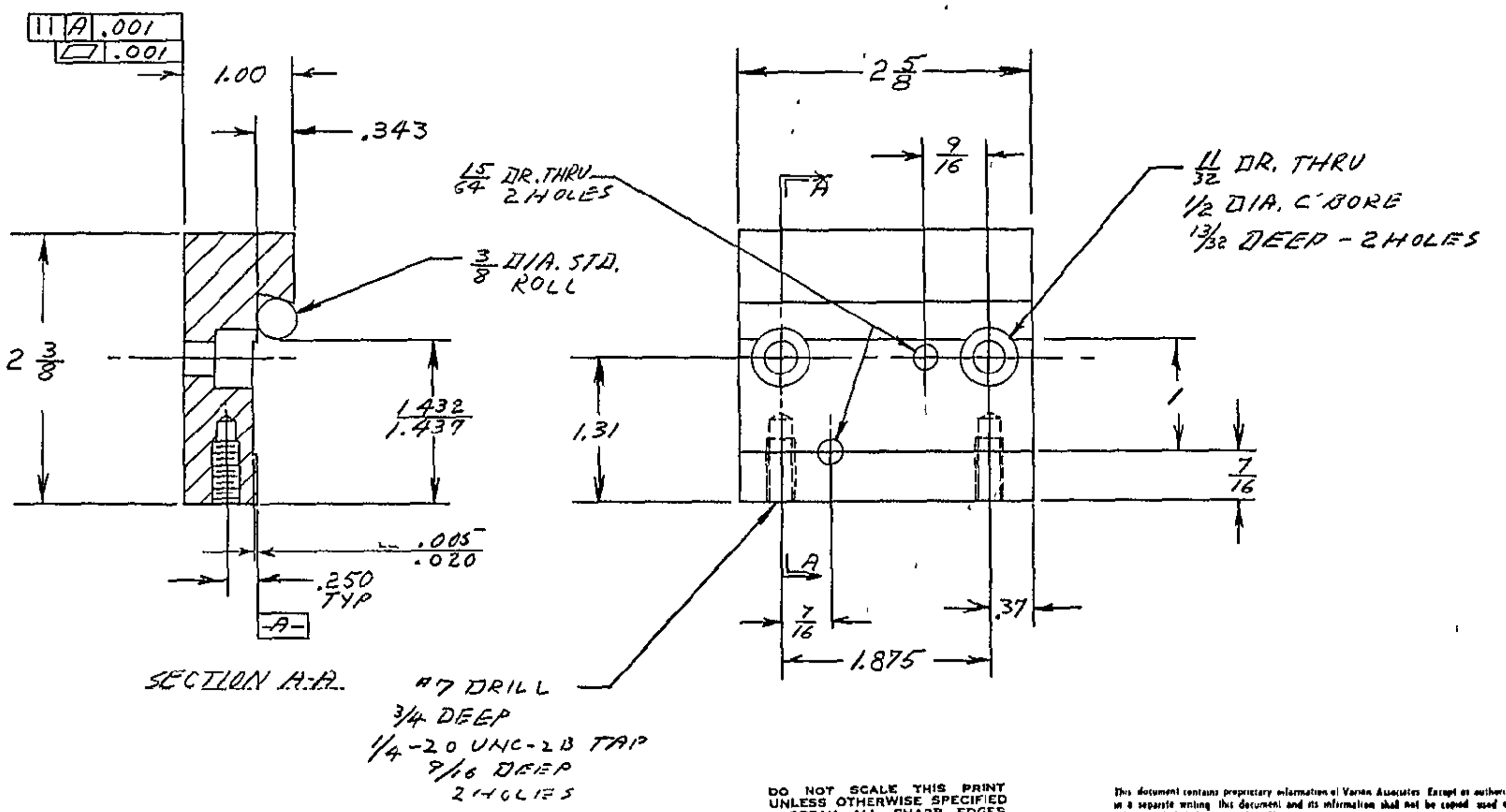
OF POOR QUALITY



DO NOT SCALE DRAWING

DO NOT SCALE THIS PRINT
UNLESS OTHERWISE SPECIFIED
BREAK ALL SHARP EDGES
DIMENSIONS ARE IN INCHES

DASH NO	TYPE OR MODEL	NEXT ASSEMBLY

REQ	PART NUMBER	DESCRIPTION OR MATERIAL	ITEM

DRAWN	DATE	APPROVED	DATE	CODE
K.Z.	10-18-77			
CHECKED	DATE	APPROVED	DATE	CLASS

BOTTOM PLATE (Work Holder)

DESCRIPTION OF CHANGE

NUM | EO | DFT | CHK | DATE | REV

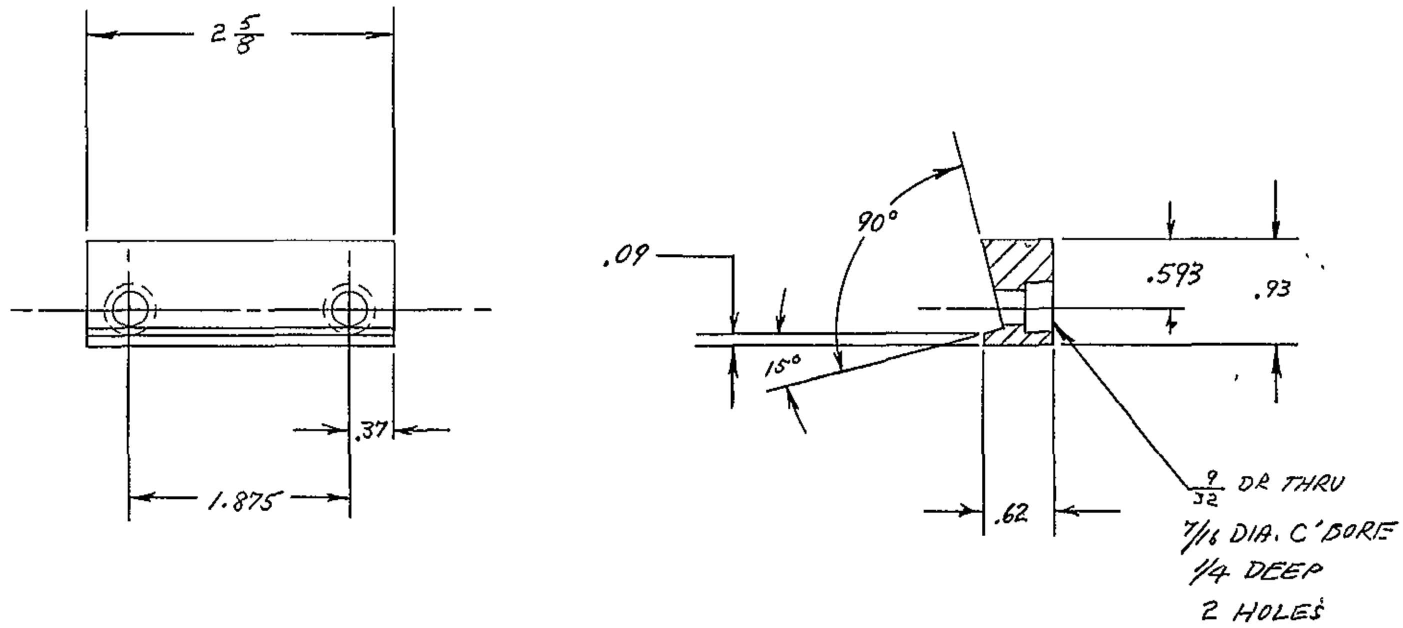
NOT OTHERWISE SPEC FRAC ± 1/64 ANG ± 1/2°
FIN 63 √ DEC X ± XX ± .01 XXX ± .005

SCALE FULL

varian

DIVISION | SIZE B | DRAWING NO S 2040 | REV

44164 JUNE66 LITHO IN U S A



DASH NO	TYPE OR MODEL	NEXT ASSEMBLY

REQ	PART NUMBER	DESCRIPTION OR MATERIAL	ITEM

DO NOT SCALE DRAWING

DO NOT SCALE THIS PRINT UNLESS OTHERWISE SPECIFIED
BREAK ALL SHARP EDGES
DIMENSIONS ARE IN INCHES

DESCRIPTION OF CHANGE

NUM / EO / DFT / CHK / DATE / REV

DRAWN	DATE	APPROVED	DATE	CODE
K. Z.	10-18-77			
CHECKED	DATE	APPROVED	DATE	CLASS

CLAMP (WORK HOLDER) LAB. SAW

NOT OTHERWISE SPEC FRAC ± 1/64 ANG ± 1/2° FIN 63 √ DEC X ± XX ± .01 XXX ± .005 SCALE FULL

varian

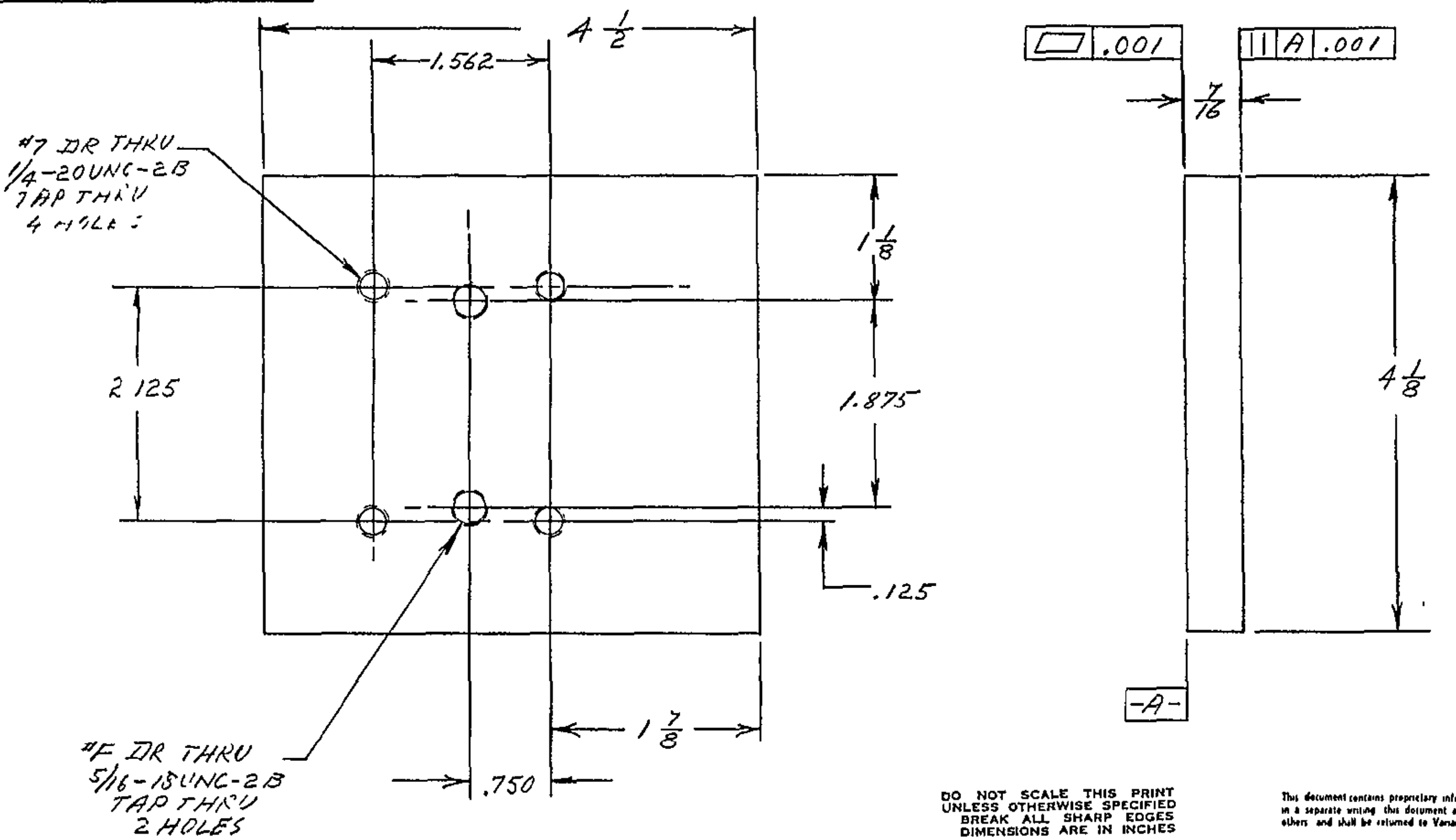
DIVISION | SIZE B | DRAWING NO S2041 | REV

441 6 4 JUNE66 LITHO IN U S A

ORIGINAL PAGE IS OF POOR QUALITY

DASH NO	TYPE OR MODEL	NEXT ASSEMBLY

REQ	PART NUMBER	DESCRIPTION OR MATERIAL	ITEM



DO NOT SCALE DRAWING

DO NOT SCALE THIS PRINT
UNLESS OTHERWISE SPECIFIED
BREAK ALL SHARP EDGES
DIMENSIONS ARE IN INCHES

DESCRIPTION OF CHANGE	
NUM	
EO	
DFT	
CHK	
DATE	
REV	

DRAWN	DATE	APPROVED	DATE	CODE
K.Z.	10-18-77			
CHECKED	DATE	APPROVED	DATE	CLASS

TOP PLATE
LAB SAW

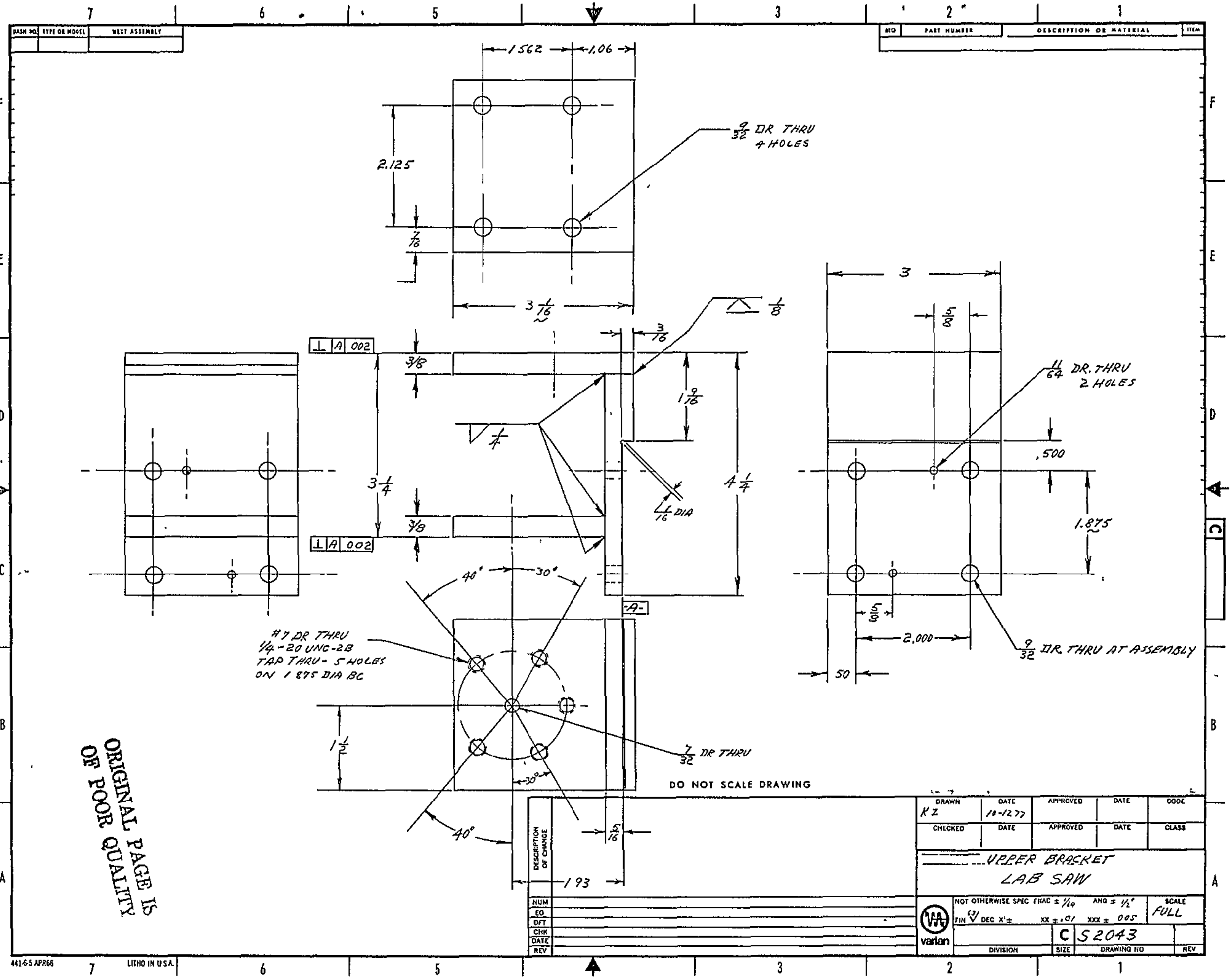
NOT OTHERWISE SPEC FRAC ± 1/64 ANG ± 1/2°
FIN 63 √ DEC X ± XX ± .01 XXX ± .005

SCALE: FULL

varian

DIVISION	SIZE	DRAWING NO	REV
	B	S 2042	

441 6 4 JUNE66 LITHO IN U S A



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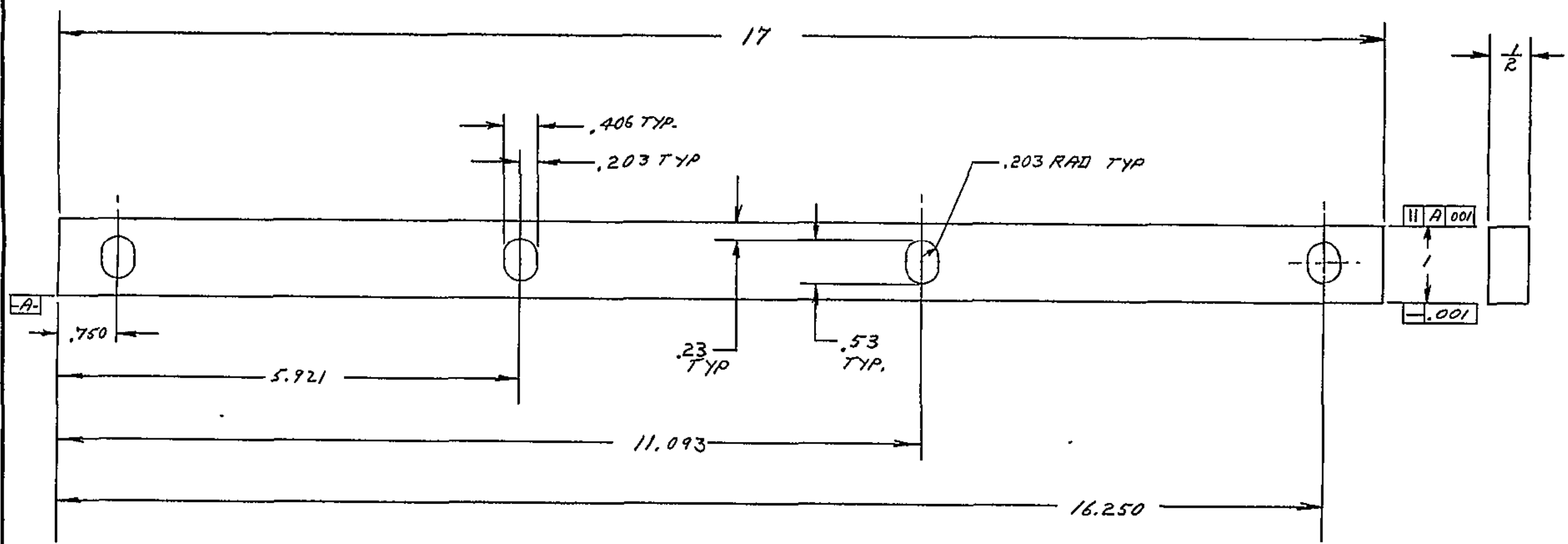
OF POOR QUALITY



NOTE: 1/32 CHAMFER ALL OUTSIDE EDGES

DO NOT SCALE DRAWING

DRAWN	DATE	APPROVED	DATE	CODE
K Z.	10-31-77			
CHECKED	DATE	APPROVED	DATE	CLASS

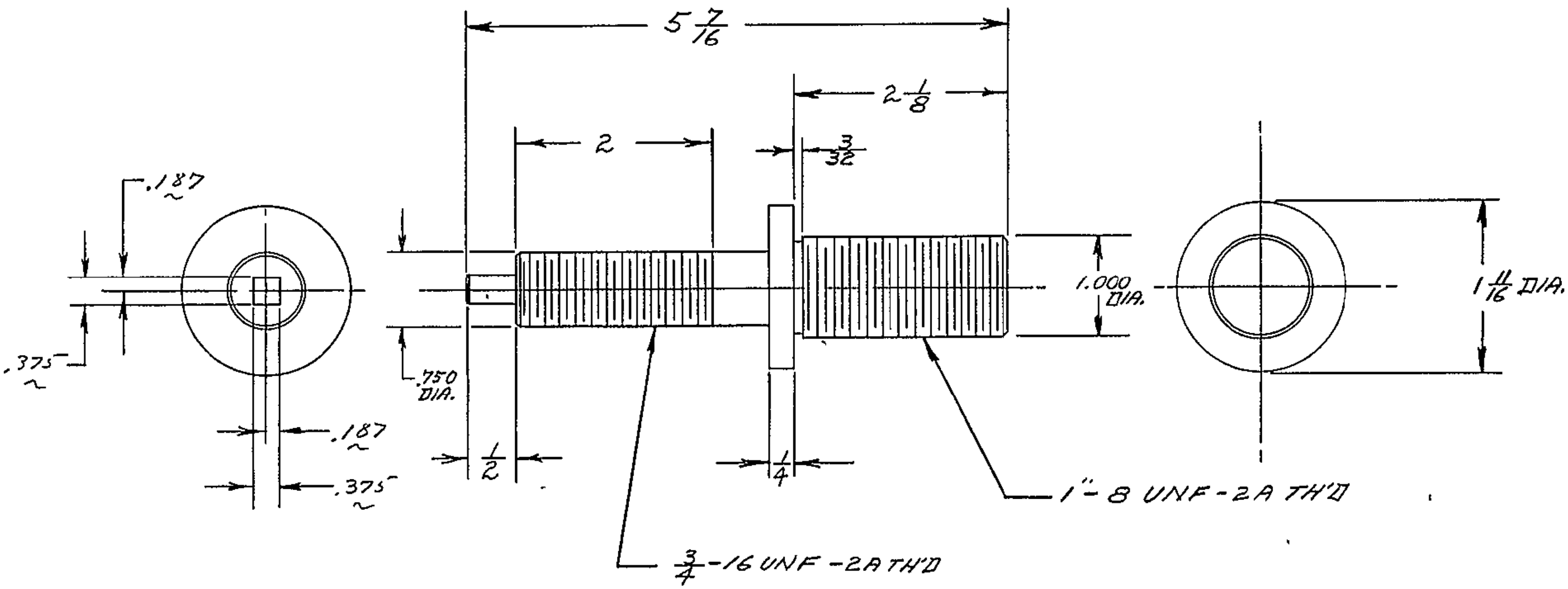
GUIDE BAR
LAB SAW

UNLESS NOT OTHERWISE SPEC FRAC ± 1/64 ANG ± FIN √ DEC X ± XX ± .01 XXX ± SCALE FULL

varian

DIVISION	SIZE	DRAWING NO	REV
	C	S 2044	

441-6-5 APR66 LITHO IN U.S.A.



DASH NO	TYPE OR MODEL	NEXT ASSEMBLY

REQ	PART NUMBER	DESCRIPTION OR MATERIAL	ITEM

DRAWN	DATE	APPROVED	DATE	CODE
KZ.	11-1-77			
CHECKED	DATE	APPROVED	DATE	CLASS

DESCRIPTION OF CHANGE

NUM / EO / DFT / CHK / DATE / REV

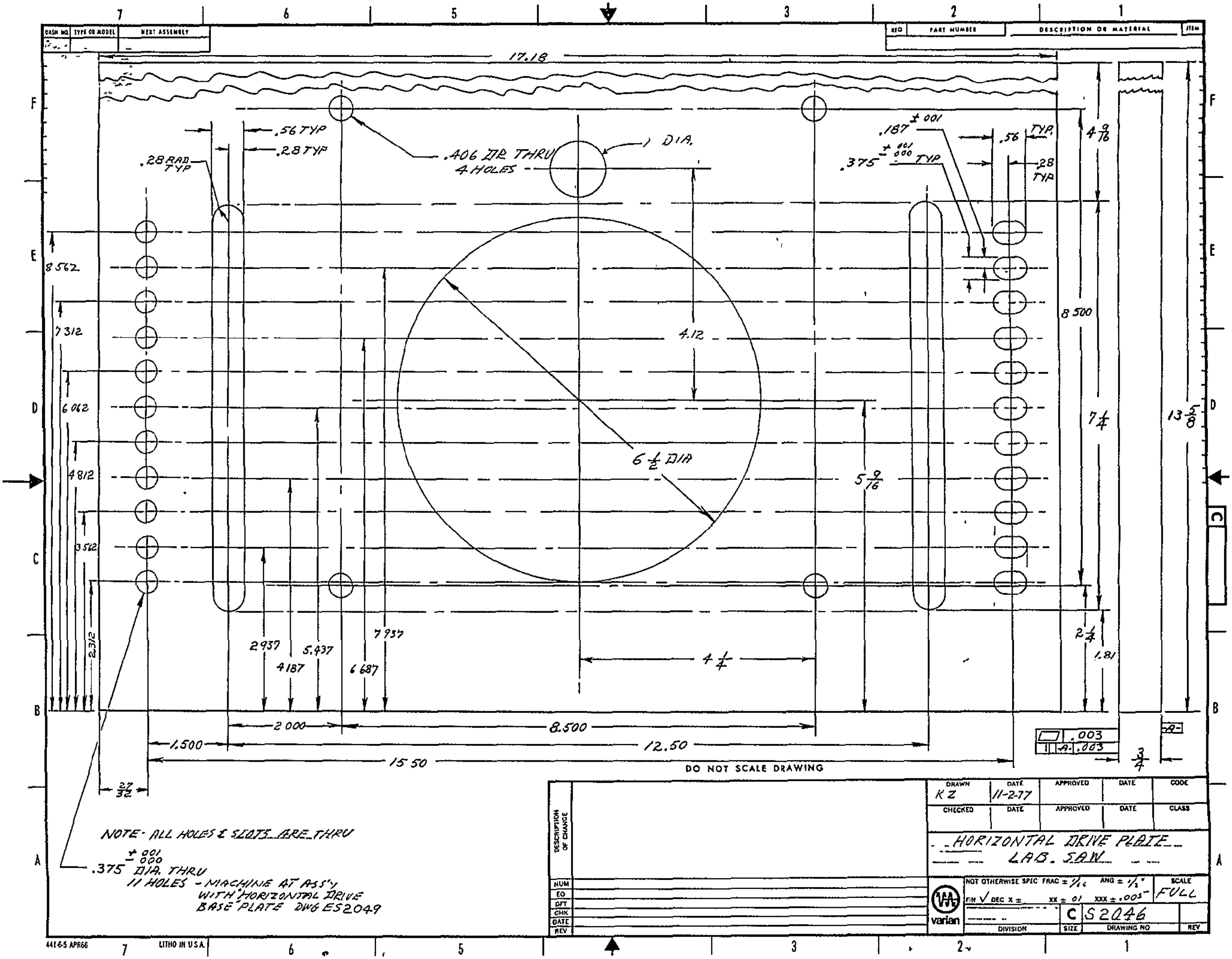
JACKING SCREW
LAB. SAW

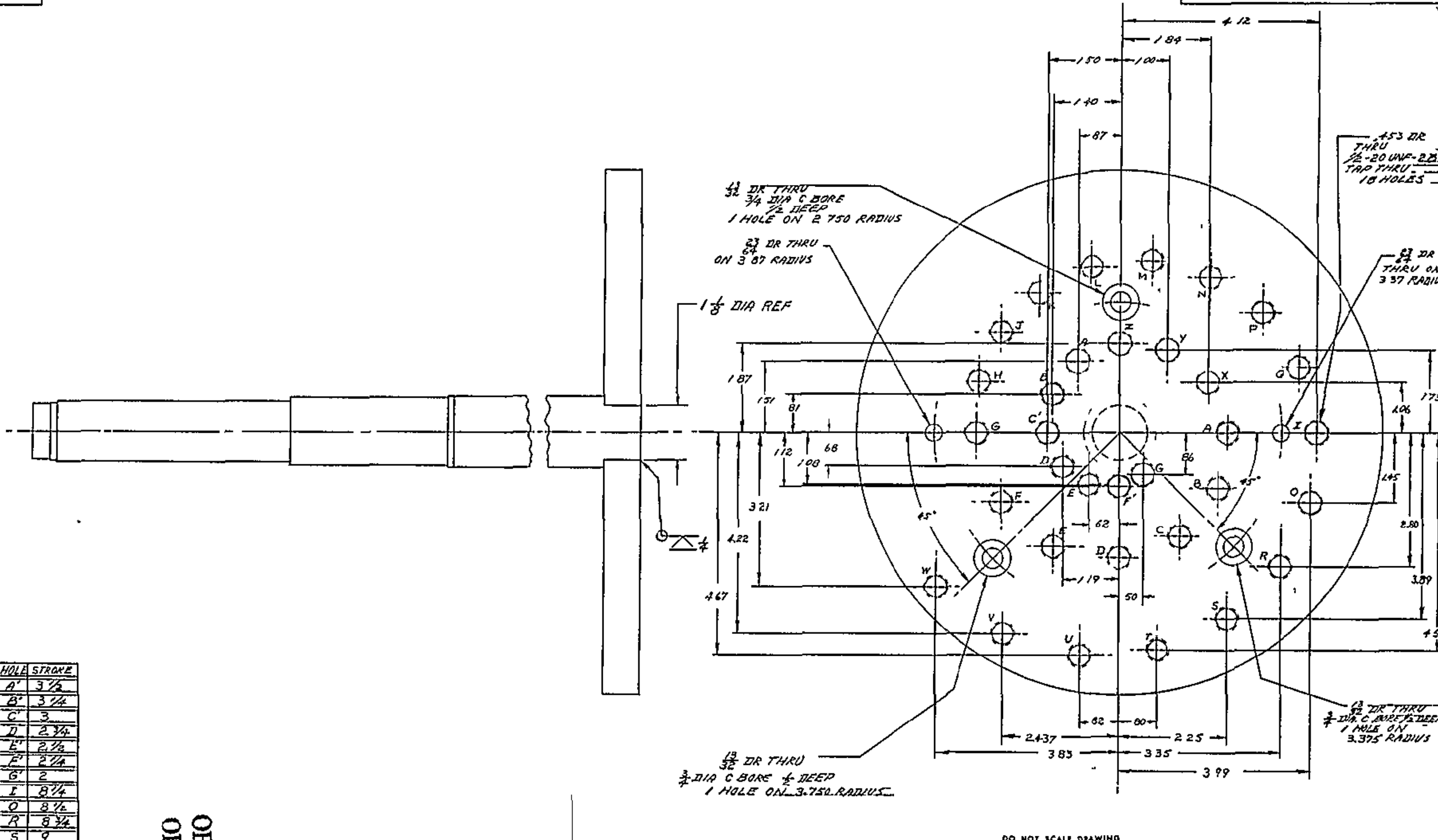
NOT OTHERWISE SPEC FRAC ± 1/64 ANG ±
FIN √ DEC X ± XX ± .01 XXX ± .005
SCALE FULL

varian

DIVISION	SIZE	DRAWING NO	REV
	B	S 2045	

ORIGINAL PAGE IS OF POOR QUALITY


17.18
.56 TYP
.28 TYP
.28 RAD TYP
.406 DR THRU 4 HOLES
1 DIA.
.187 ± .001
.375 +.001 -.000 TYP
.56 TYP.
.28 TYP
4 9/16
8.562
7.312
6.062
4.812
3.562
2.312
4.12
8.500
7 1/4
13 5/8
6 1/2 DIA
5 9/16
2 1/4
1.81
2.937
4.187
5.437
6.687
7.937
4 1/4
2.000
8.500
1.500
12.50
15.50
27/32
3/4
.003
A .003
-A-
DO NOT SCALE DRAWING
NOTE - ALL HOLES & SLOTS ARE THRU
.375 +.001 -.000 DIA. THRU
11 HOLES - MACHINE AT ASS'Y WITH HORIZONTAL DRIVE BASE PLATE DWG ES2049
DRAWN KZ
DATE 11-2-77
CHECKED
APPROVED
CODE
CLASS
HORIZONTAL DRIVE PLATE
LAB. SAW
NOT OTHERWISE SPEC FRAC ± 1/64 ANG ± 1/2°
FIN √ DEC X ± XX ± .01 XXX ± .005
SCALE FULL
C S2046
DIVISION SIZE DRAWING NO REV
varian
DESCRIPTION OF CHANGE
NUM EO DFT CHK DATE REV
CASH NO. TYPE OR MODEL NEXT ASSEMBLY
REQ PART NUMBER DESCRIPTION OR MATERIAL ITEM
441-6-5 APR66
LITHO IN U.S.A.



HOLE	STROKE
A'	3 1/2
B'	3 1/4
C'	3
D'	2 3/4
E'	2 1/2
F'	2 1/4
G'	2
I	8 1/4
O	8 1/2
R	8 3/4
S	9
T	9 1/4
U	9 1/2
V	9 3/4
W	10
X	4 1/4
Y	4
Z	3 3/4

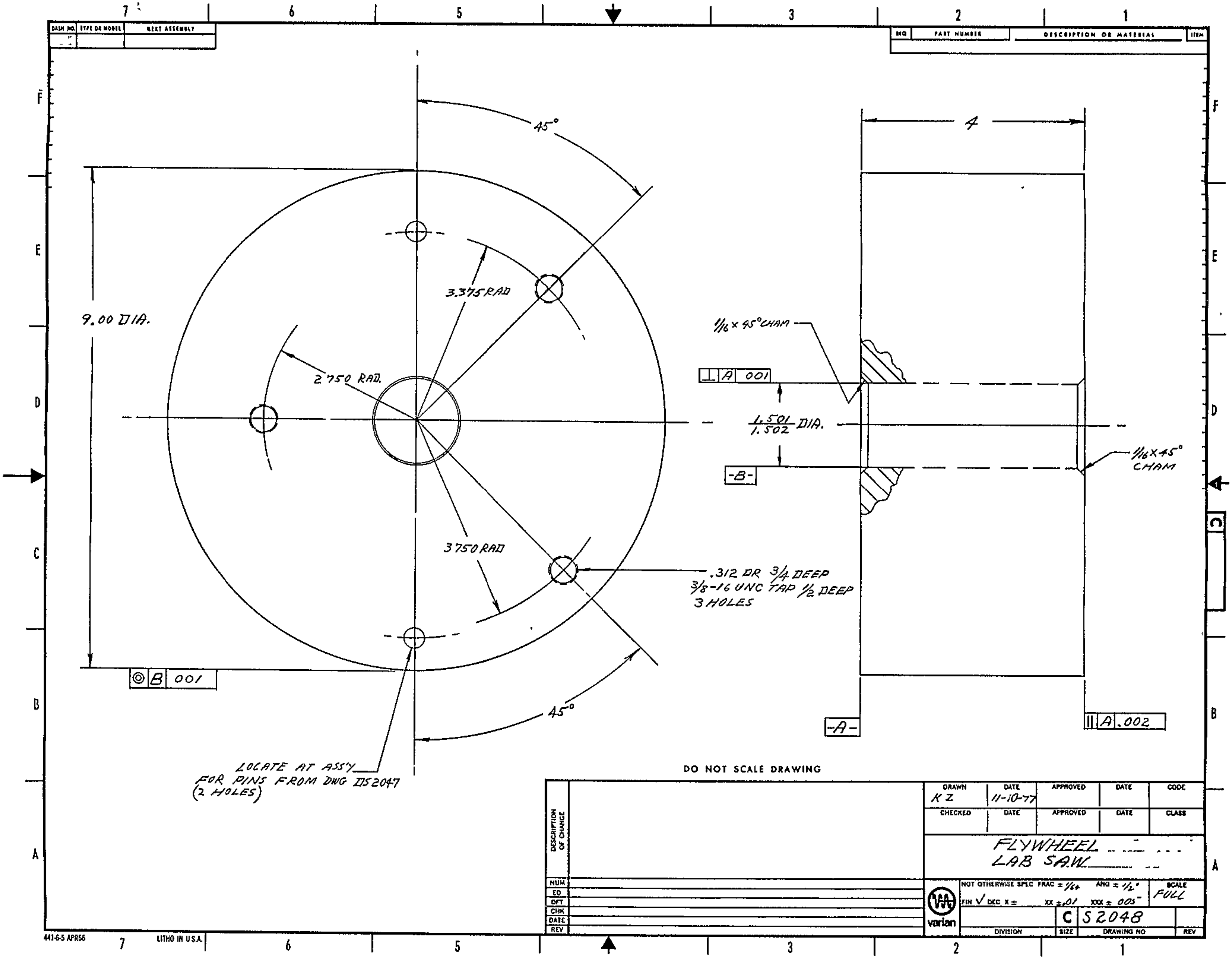
DO NOT SCALE DRAWING

DRAWN	DATE	SCALE	SIZE	DRAWING NO.
KZ	11-9-77	FULL	D	S2047

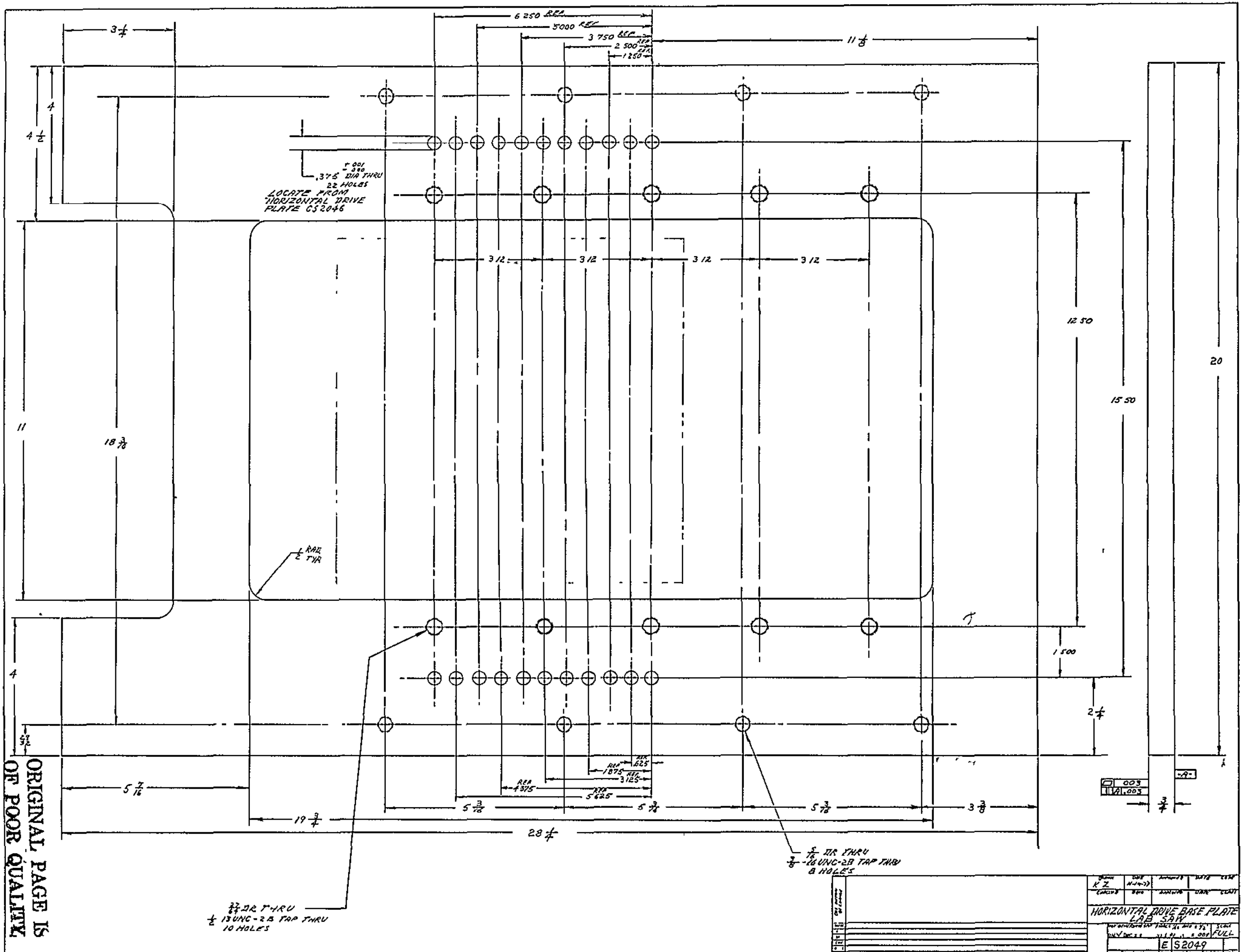
DRIVE PLATE
LAB SAW

varian

SHEET 2 OF 2



DASH NO. | TYPE OR MODEL | NEXT ASSEMBLY
REQ | PART NUMBER | DESCRIPTION OR MATERIAL | ITEM
45°
4
9.00 DIA.
3.375 RAD
2.750 RAD.
1/16 × 45° CHAM
⊥ A .001
1.501/1.502 DIA.
-B-
1/16 × 45° CHAM
3750 RAD
.312 DR 3/4 DEEP
3/8-16 UNC TAP 1/2 DEEP
3 HOLES
◎ B .001
45°
-A-
∥ A .002
LOCATE AT ASS'Y
FOR PINS FROM DWG D52047
(2 HOLES)
DO NOT SCALE DRAWING
DESCRIPTION OF CHANGE
NUM
EO
DFT
CHK
DATE
REV
DRAWN KZ
DATE 11-10-77
APPROVED
DATE
CODE
CHECKED
DATE
APPROVED
DATE
CLASS
FLYWHEEL
LAB SAW
NOT OTHERWISE SPEC FRAC ± 1/64 ANG ± 1/2°
FIN √ DEC X ± XX ± .01 XXX ± .005
SCALE FULL
varian
C S2048
DIVISION
SIZE
DRAWING NO
REV
441-6-5 APR66
LITHO IN U.S.A.



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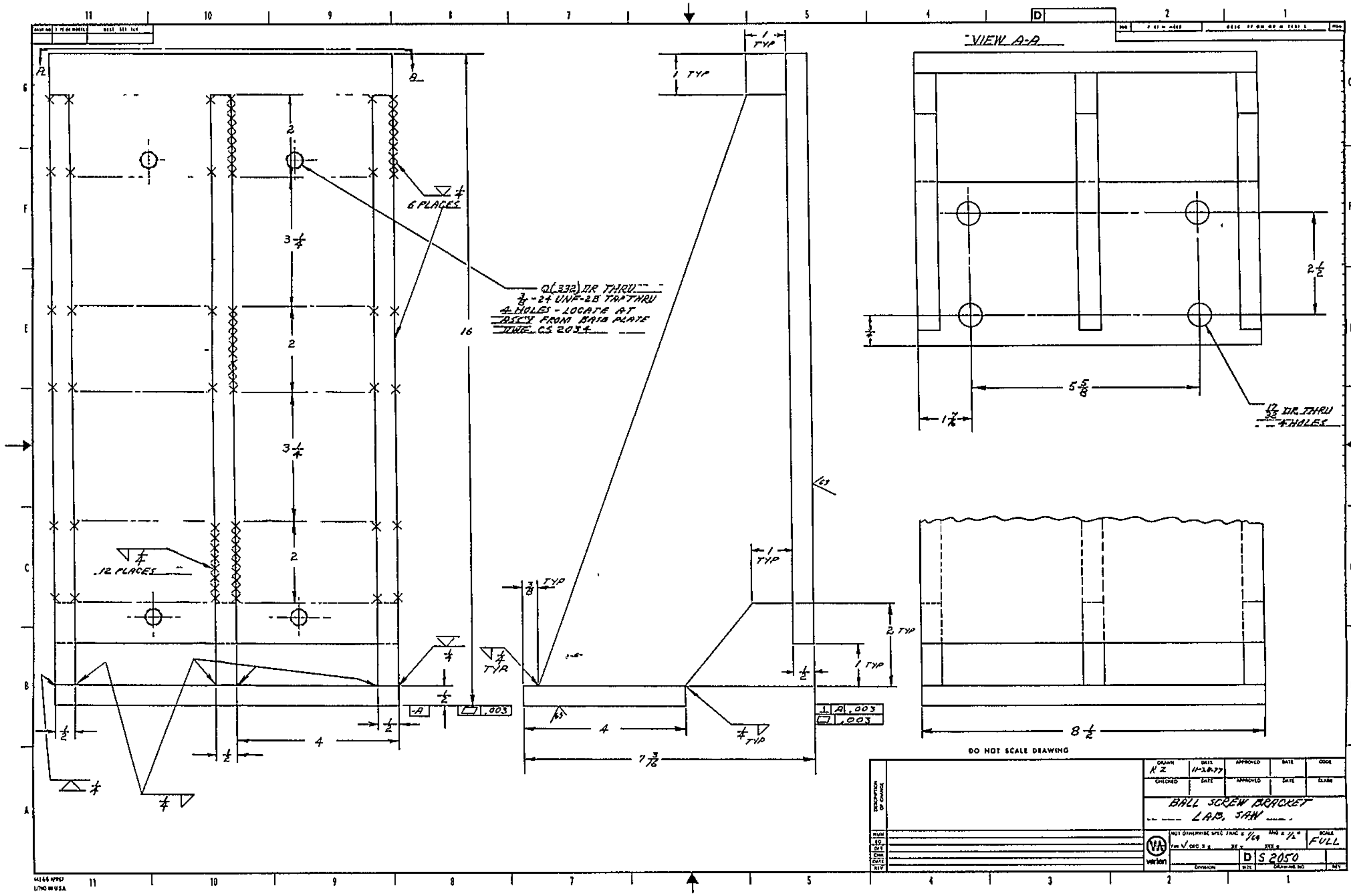
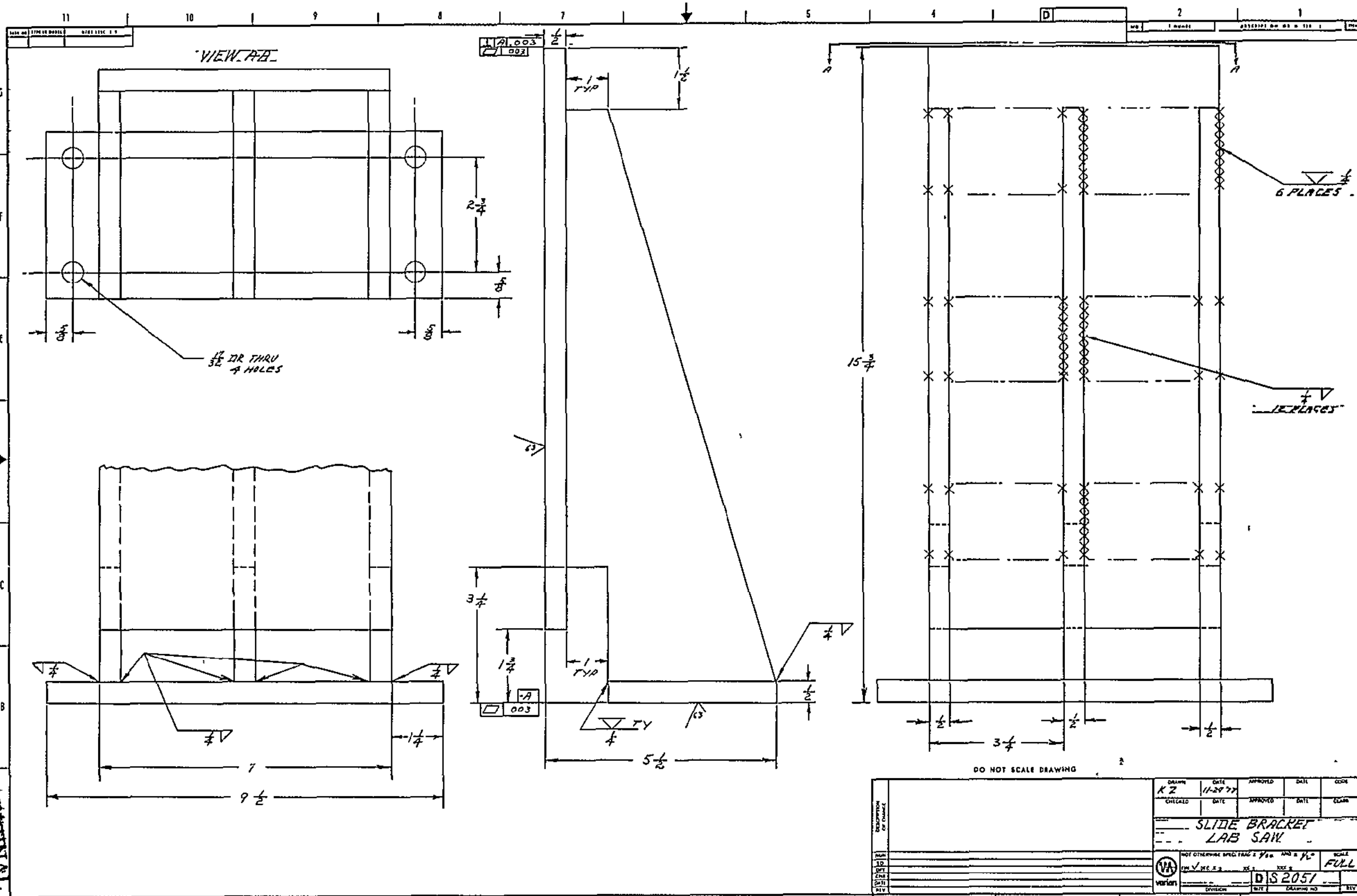


VIEW A-A
1 TYP
Q(.332) DR THRU
3/8-24 UNF-2B TAP THRU
4 HOLES - LOCATE AT
ASS'Y FROM BASE PLATE
DWG CS 2034
6 PLACES
12 PLACES
16
2
3 1/4
4
7 3/16
8 1/2
5 5/8
2 1/2
1 7/8
2 TYP
17/32 DR THRU
4 HOLES
.003
DO NOT SCALE DRAWING
DRAWN K Z
DATE 11-28-77
BALL SCREW BRACKET
LAB, SAW
SCALE FULL
D S 2050
varian



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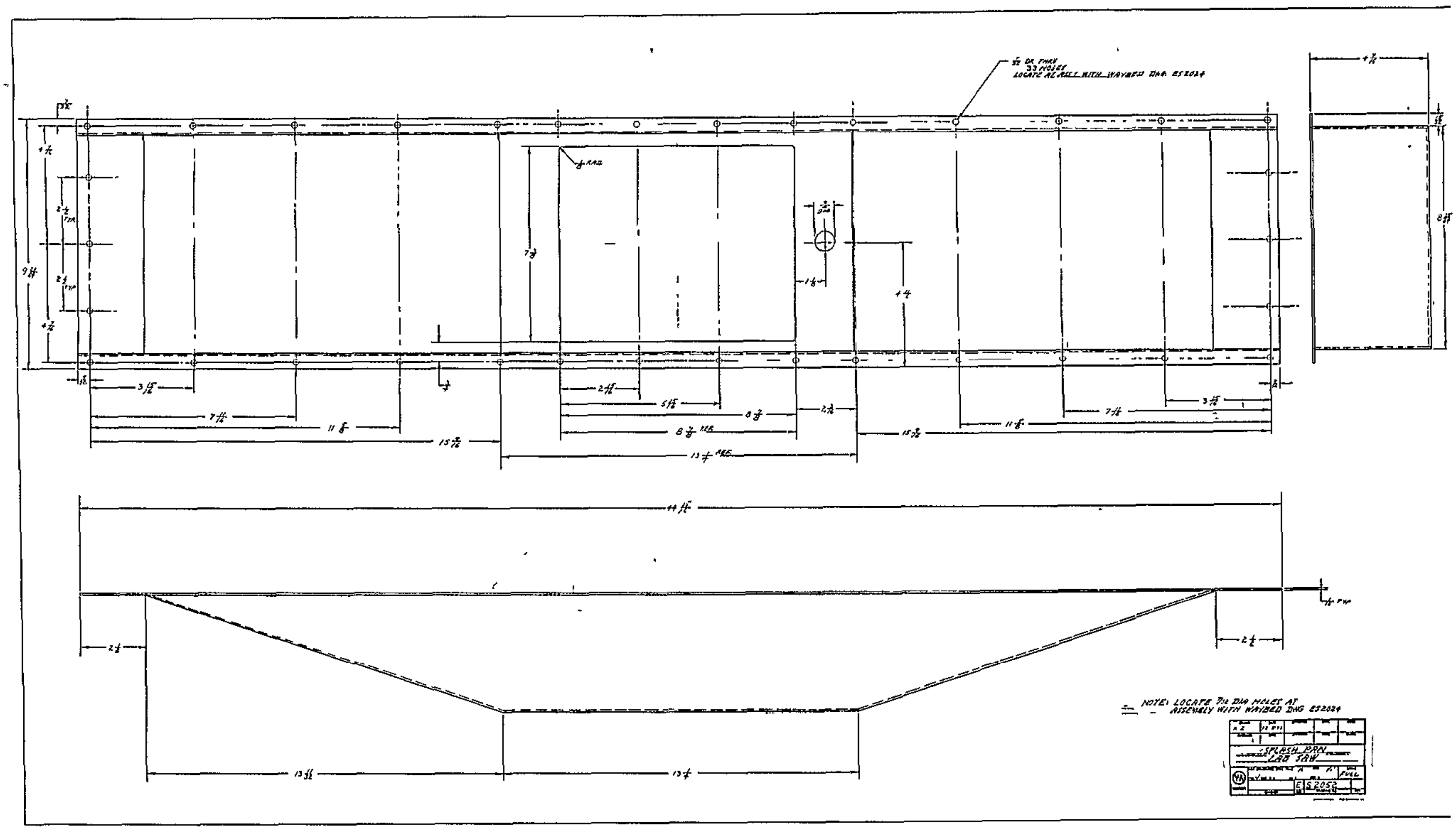
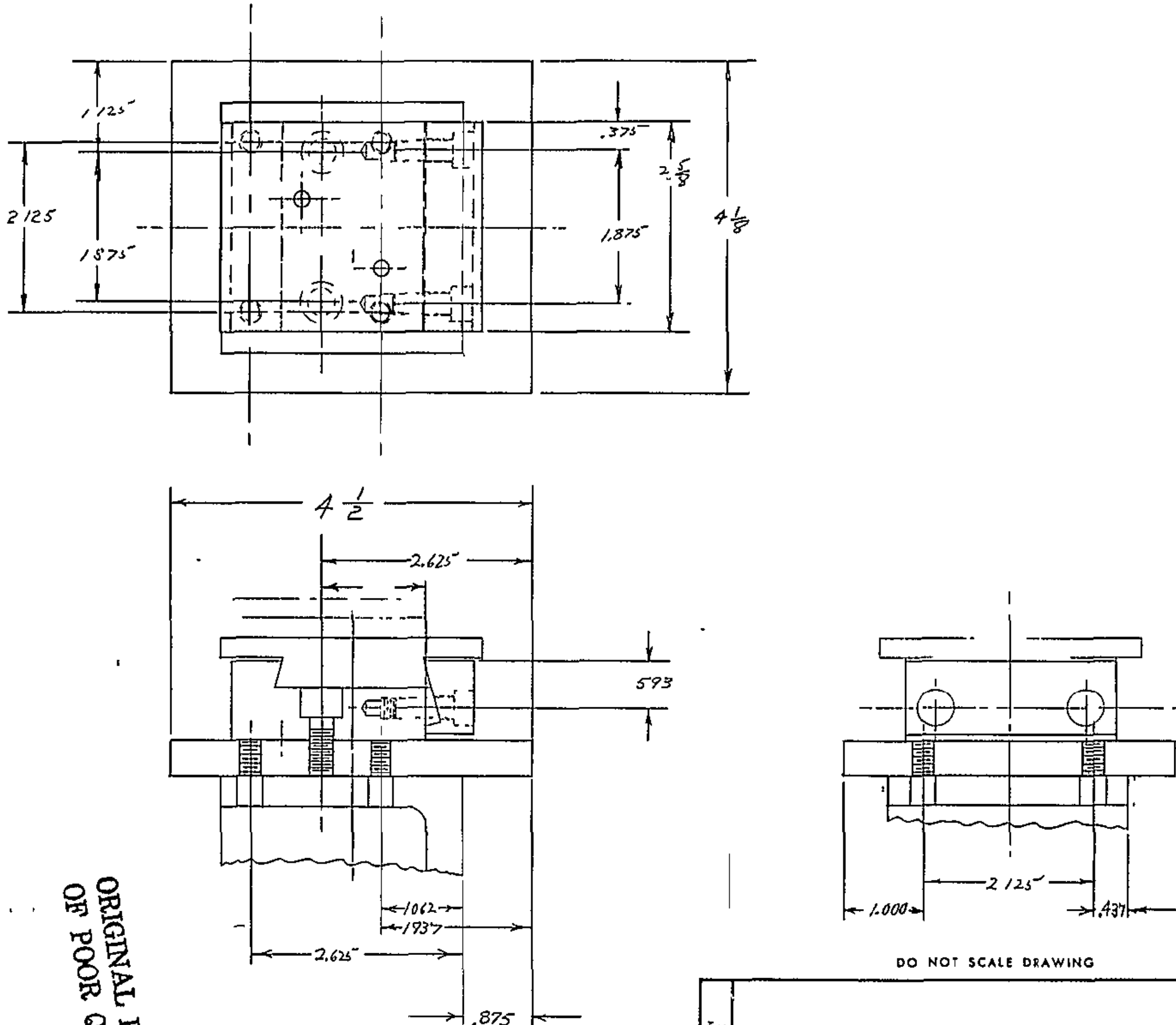


LOCATE AT ASSY WITH WAYBED DWG ES2024
NOTE: LOCATE 7/32 DIA HOLES AT ASSEMBLY WITH WAYBED DWG ES2024
SPLASH PAN
LAB SAW
FULL
ES2052



DO NOT SCALE DRAWING

DRAWN	DATE	APPROVED	DATE	CODE
KZ	10-13-77			
CHECKED	DATE	APPROVED	DATE	CLASS

WORK HOLDER LAYOUT
LAB SAW

NOT OTHERWISE SPEC FRAC ± ANG ±
FIN √ DEC X ± XX ± XXX ±

SCALE FULL

varian

DIVISION | SIZE C | DRAWING NO S 2053 | REV

DESCRIPTION OF CHANGE
NUM
EO
DFT
CHK
DATE
REV

DASH NO. | TYPE OF MODEL | NEXT ASSEMBLY

REQ | PART NUMBER | DESCRIPTION OR MATERIAL | ITEM

441-6-5 APR66 LITHO IN U.S.A.

APPENDIX II

MAN-HOURS AND COSTS

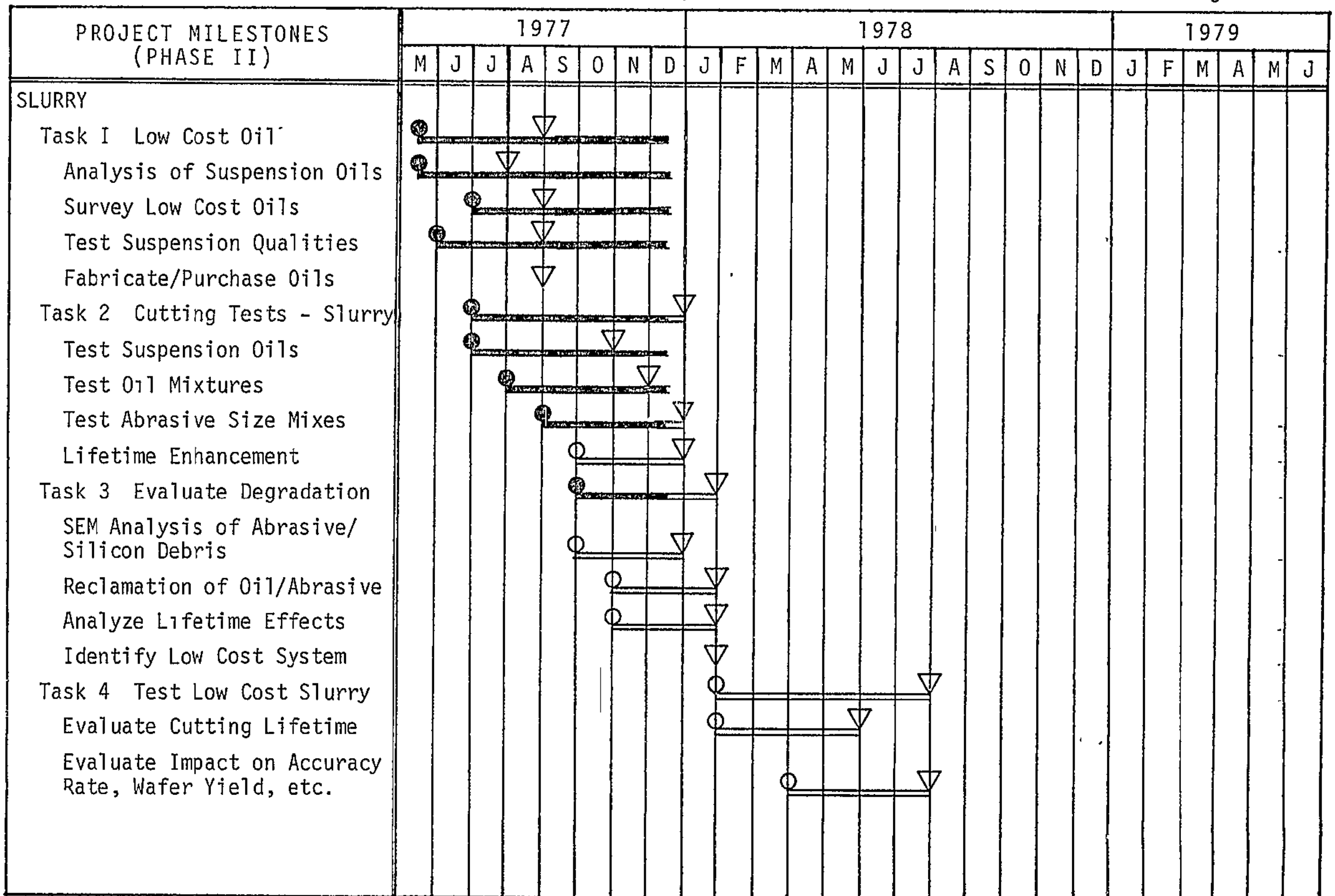
PROGRAM PLAN (UPDATED)

MAN-HOURS AND COSTS (PHASE II)

During the reporting period of September 19, 1977 to December 17, 1977, total man-hours were 2768.2 hours and total costs were $119,367. Previous expenditures were 2659.3 hours and $136,242. As of December 17, 1977, total program man-hours were 5427.5 hours and total program costs were $255,609.

SLICING OF SILICON INTO SHEET MATERIAL

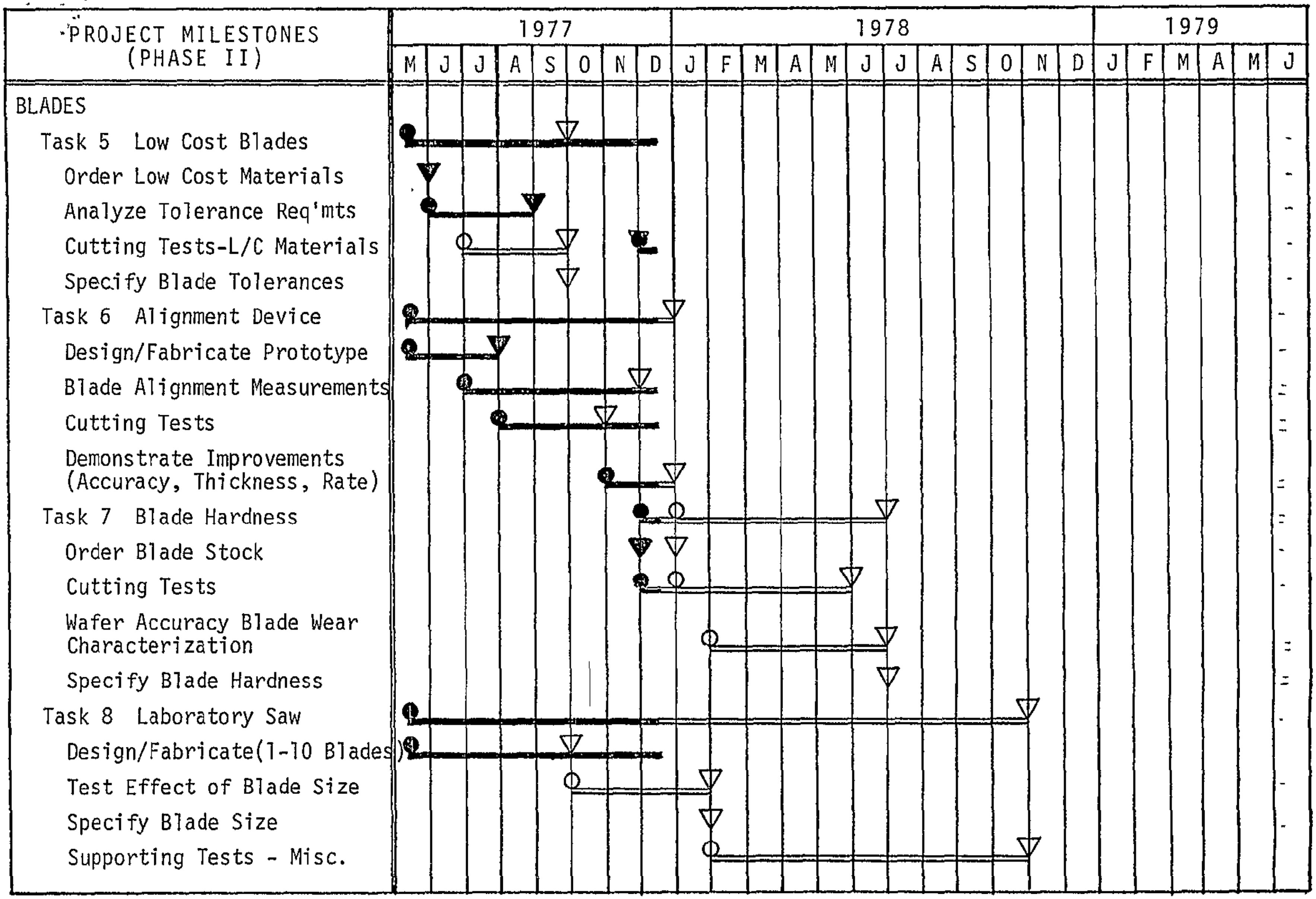
Varian Associates/Lexington Vacuum Division
JPL Contract 954374
Starting Date: 1/9/76 (I) 5/19/77 (II)



SCH 6/15/77
Updated 1/12/78

SLICING OF SILICON INTO SHEET MATERIAL

Varian Associates/Lexington Vacuum Division
JPL Contract 954374
Starting Date: 1/9/76 (I) 5/19/77 (II)



SCH 6/15/77
Updated 1/12/78

SLICING OF SILICON INTO SHEET MATERIAL

Varian Associates/Lexington Vacuum Division
JPL Contract 954374
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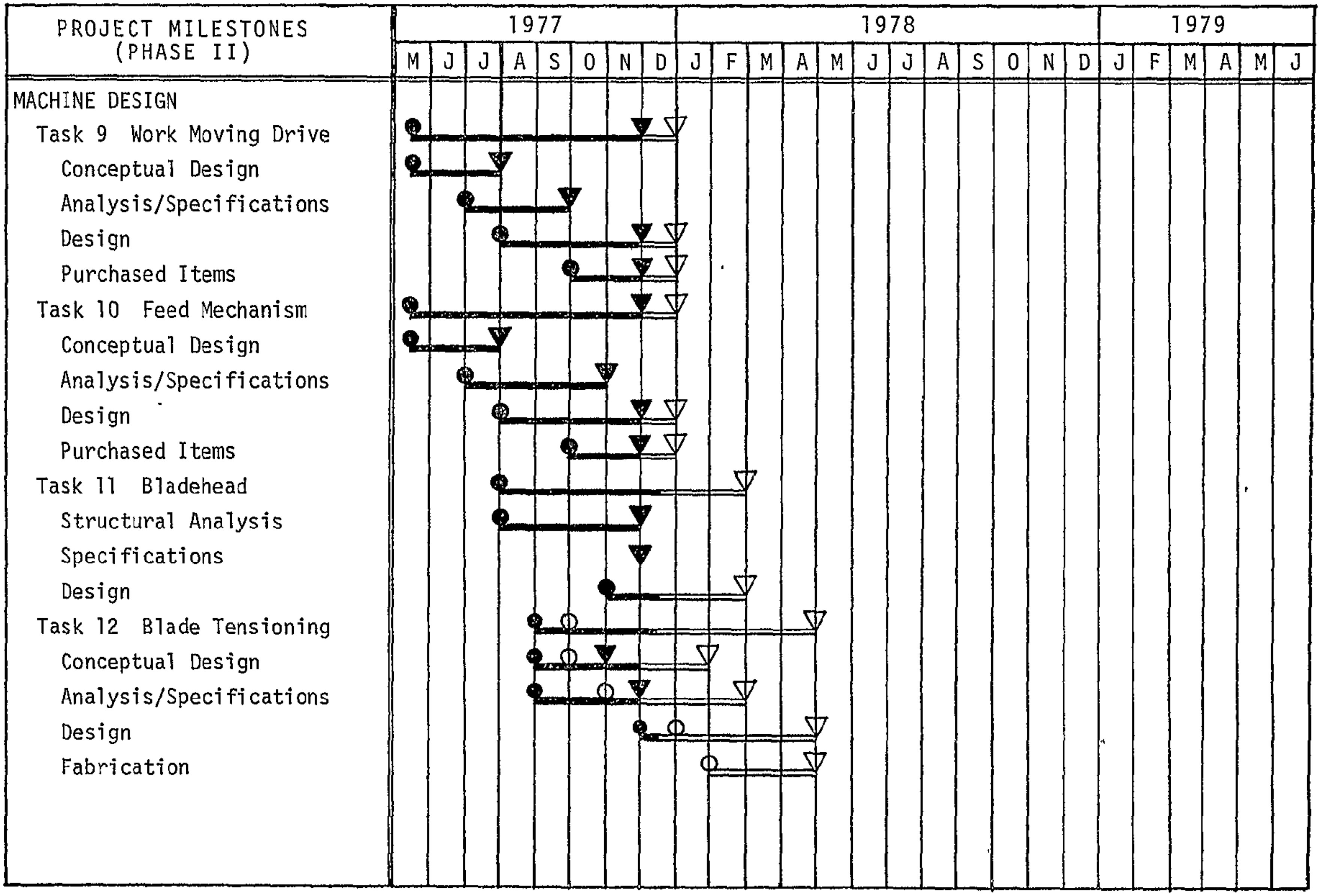

SCH 6/15/77
Updated 1/12/78

SLICING OF SILICON INTO SHEET MATERIAL

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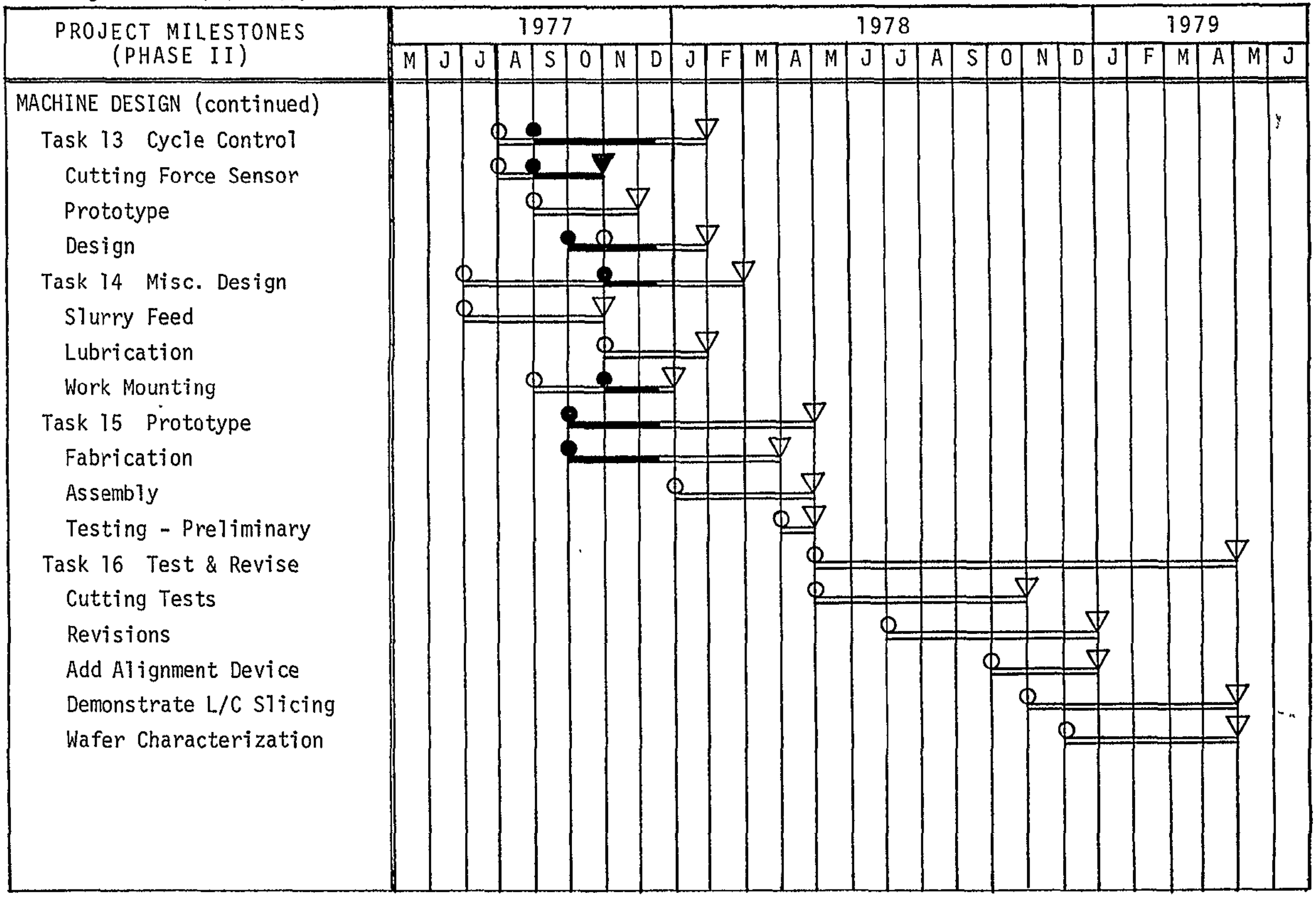
JPL Contract 954374
Starting Date: 1/9/76 (I) 5/19/77 (II)

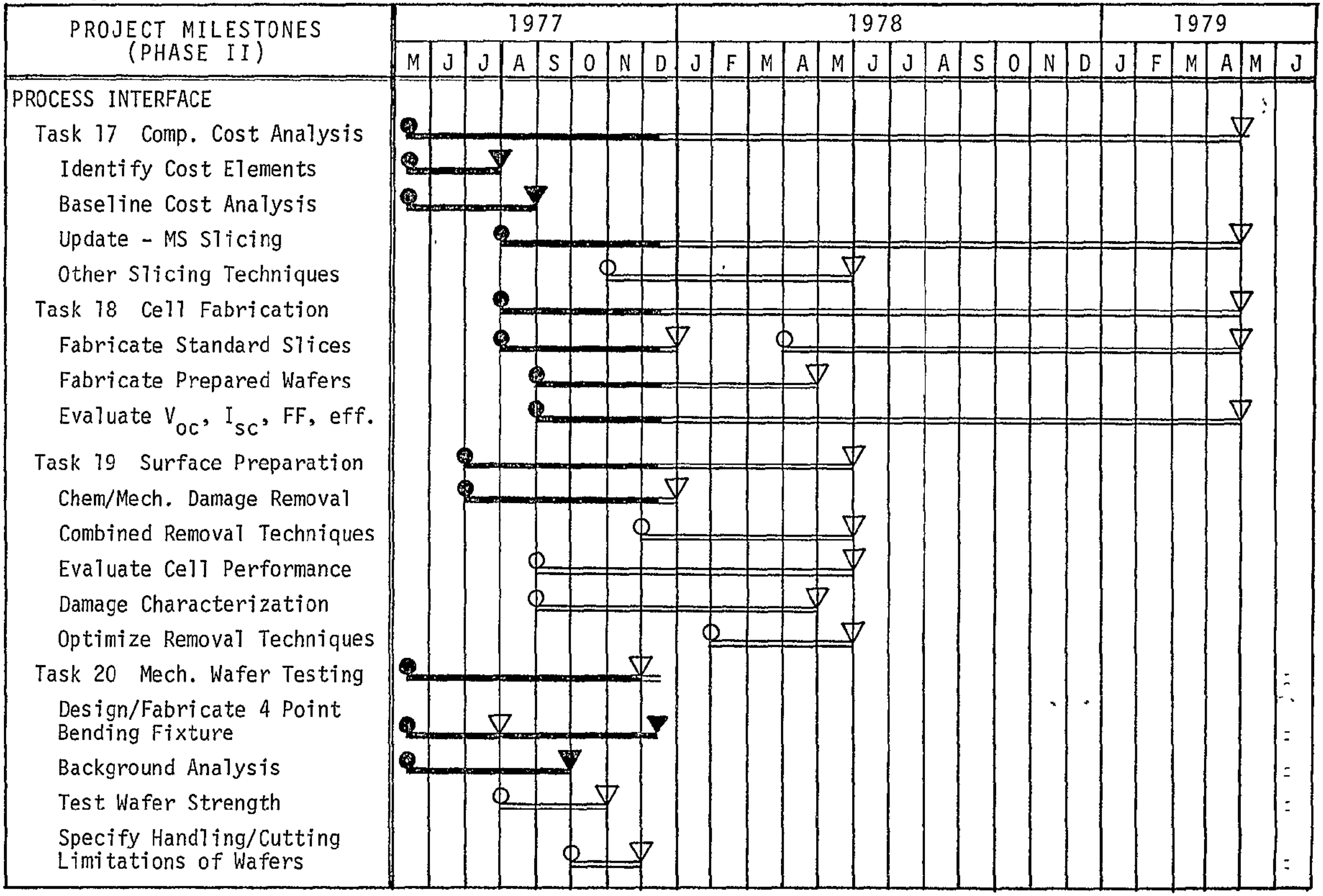


SCH 6/15/77
Updated 1/12/78

SLICING OF SILICON INTO SHEET MATERIAL

Varian Associates/Lexington Vacuum Division
JPL Contract 954374
Starting Date: 1/9/76 (I) 5/19/77 (II)

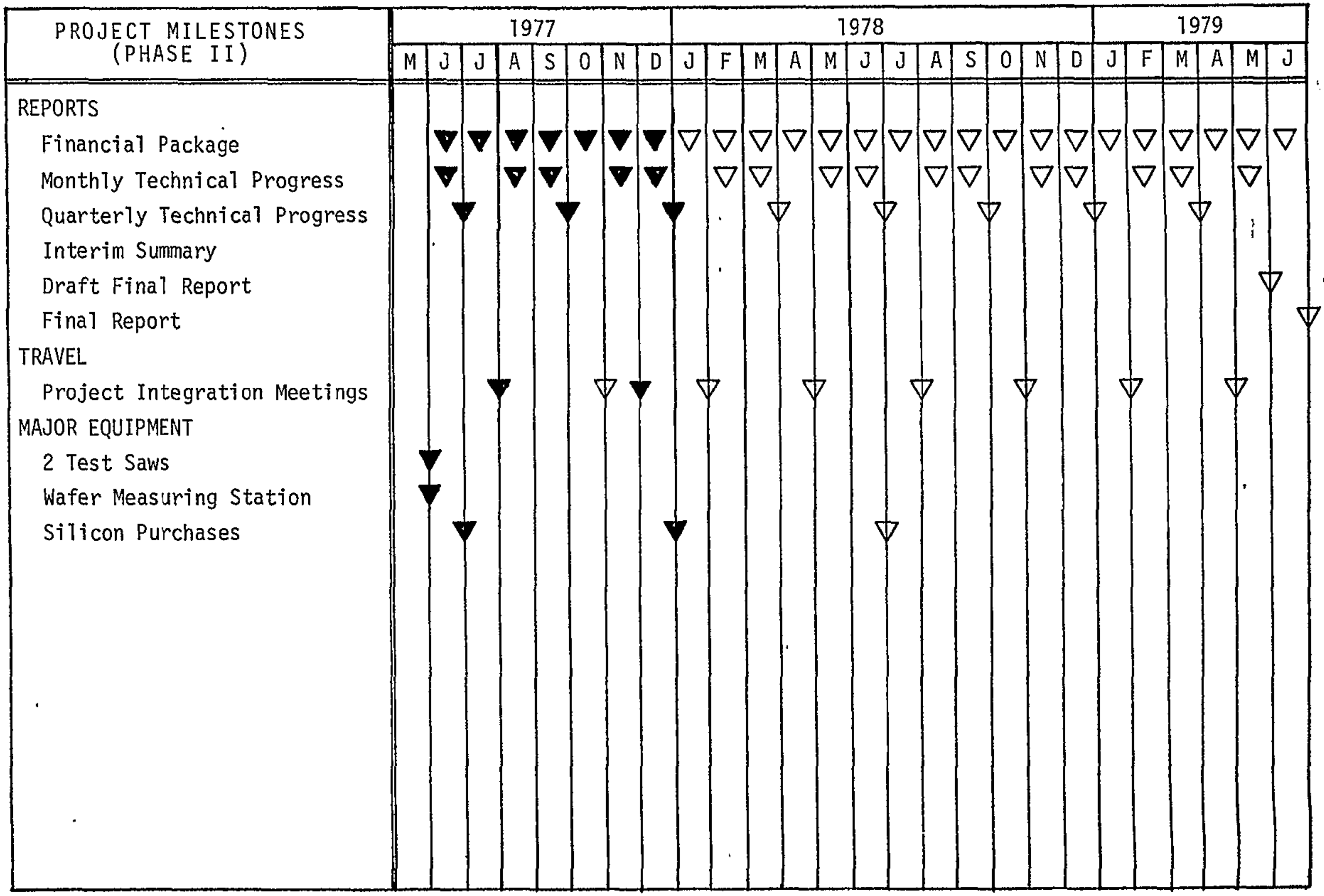
Phase II
Program Plan



SCH 6/15/77
Updated 1/12/78

SLICING OF SILICON INTO SHEET MATERIAL

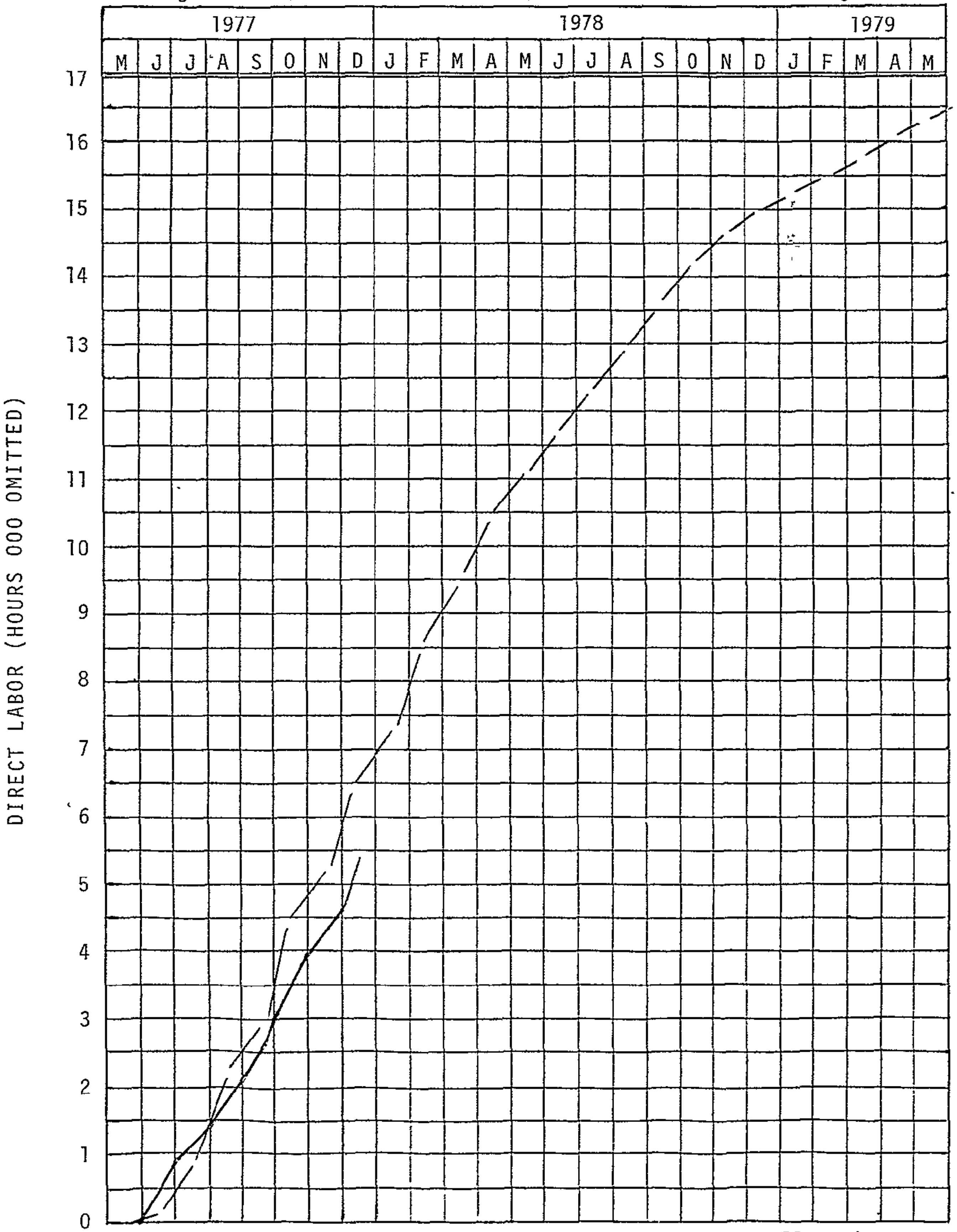
Varian Associates/Lexington Vacuum Division
JPL Contract 954374
Starting Date: 1/9/76 (I) 5/19/77 (II)



SCH 6/15/77
Updated 1/12/78

SLICING OF SILICON INTO SHEET MATERIAL

Varian Associates/Lexington Vacuum Division
JPL Contract 954374
Starting Date: 1/9/76 (I) 5/19/77 (II)



SCH 6/14/77
Updated 1/12/78

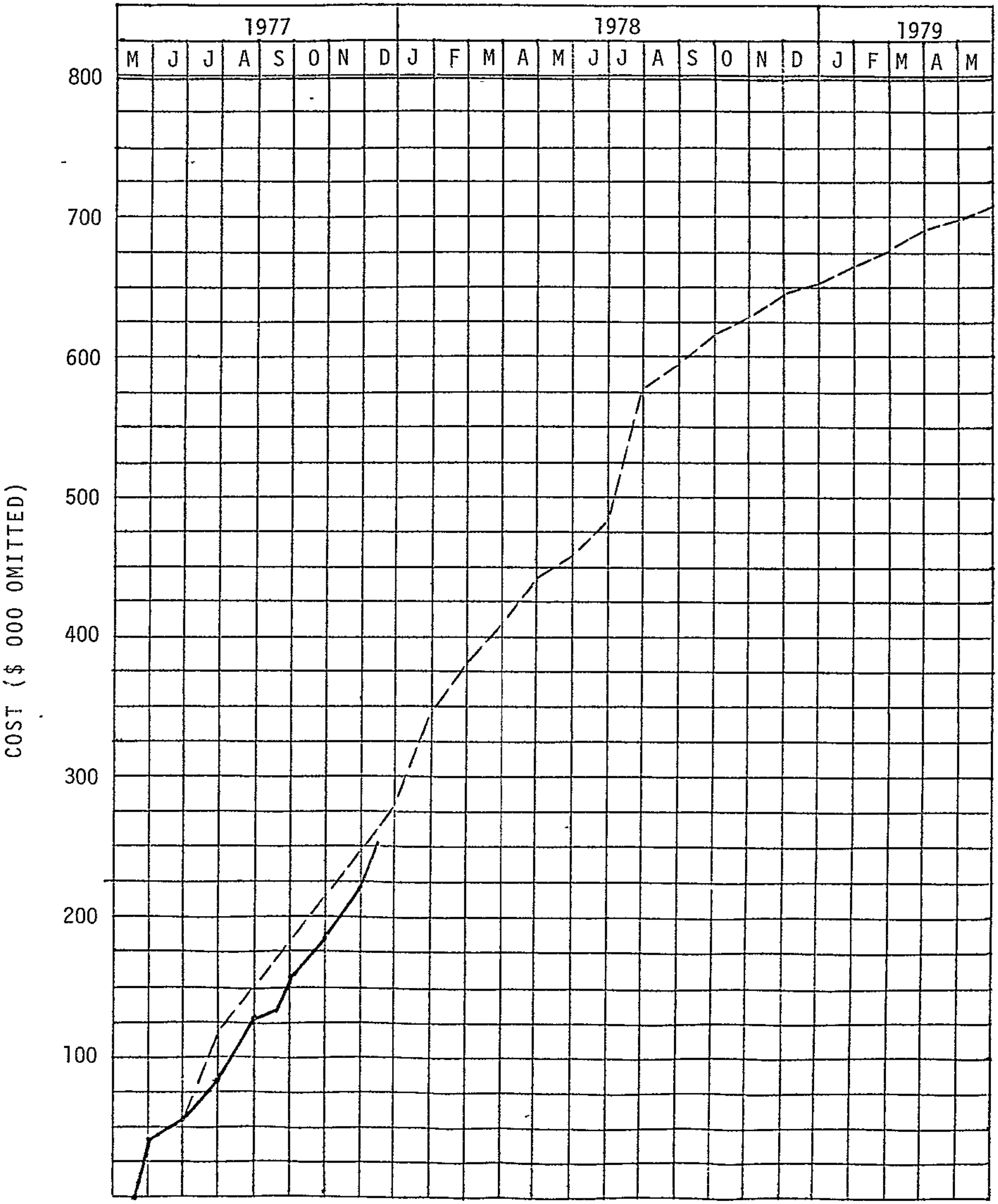
Total Hours: 16,435
Hours to Date: 5427.5

Planned -----
Incurred ———

PROGRAM LABOR SUMMARY

SLICING OF SILICON INTO SHEET MATERIAL

Varian Associates/Lexington Vacuum Division
JPL Contract 954374
Starting Date: 1/9/76 (I) 5/19/77 (II)



SCH 6/14/77
Updated 1/12/78

Total Cost: $708,210
Incurred Cost: $255,609

Planned -------
Incurred ———

PROGRAM COST SUMMARY